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THE UNIVERSITY OF ALBERTA

LABORATORY ACTIVITY IN THE JUNIOR HIGH SCHOOL SCIENCE CLASSROOM

by

GERHARD (GERRY) E. JESKE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF SECONDARY EDUCATION

EDMONTON, ALBERTA
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ABSTRACT

The study is an examination of what science laboratory activity is at the junior high school level, and the learning outcomes attributed to it by participating students and teachers.

Eight data gathering techniques were employed over a two to three week interval at each of the three Alberta Junior High Schools visited. While at each school a science opinionnaire was administered to all of the students within the observed class. From students' responses on the opinionnaire the students having the highest, intermediate, and lowest scores were selected for interviewing, observing with the Science Laboratory Interaction Categories (SLIC) checklist and for providing samples of their laboratory reports. Field notes were recorded during the laboratory activities observed, class pre- and post-laboratory discussions were tape recorded, copies of structured student laboratory investigations were obtained, and teachers were interviewed.

Copies of the structured laboratory investigations handed out in class, and students' laboratory reports were analyzed for the level of student inquiry. Researcher field notes, transcribed teacher and student interviews, and transcribed pre- and post-laboratory class discussions were searched for recurring themes relevant to the organization, interaction dynamics, and impacts of

laboratory activity. The Science Laboratory Interaction Categories (SLIC) checklist observations were analyzed for the percentage of observed laboratory time spent by the selected students in each of the SLIC categories. The science opinionnaire data was categorized with respect to the "Nature" and "Impacts" of laboratory activity.

It was found in the study that:

1. Students' attitude toward science and laboratory work became more positive with an increase in students' experience with laboratory activities.
2. Both teachers and students considered laboratory activities as increasing student understanding, and as motivating students to learn.
3. The learning outcomes attributed to laboratory activities need to be considered relative to the learning situations for which they have been ascribed.
4. Students prefer teachers to interact with them at the individual group level rather than the whole class level during laboratory activities.
5. Students and teachers at the junior high school level showed a preference for laboratory investigations which were structured by the teacher and/or laboratory manual.

ACKNOWLEDGEMENTS

I wish to extend my sincere thanks to my advisory committee, Dr. Brouwer, Dr. Gustafson, Dr. Samiroden, and Dr. Wangler, for their valuable advice, encouragement and understanding. Particular appreciation is extended to Dr. Brouwer and Dr. Nay for their valuable guidance and understanding. I also wish to thank Dr. Beauchamp, Dr. Kass, and Dr. Jacknicke for their valuable suggestions.

I wish to express appreciation to the students who responded to the opinionnaire, and also those who were interviewed. I sincerely thank the three teachers (referred to in the study as Mr. Scheele, Mrs. Dalton, and Mr. Priestley) who allowed me to observe their classes and agreed to be interviewed. I am indebted to the teachers and students who participated in the pilot study.

A sincere thanks also goes to my wife, Nancy, for her loving support, patience, understanding, and assistance with the word processing. To my wife, Nancy, I dedicate this dissertation.

TABLE OF CONTENTS

CHAPTER PAGE

I INTRODUCTION TO THE STUDY 1

Statement of Problem 3

Importance of the Study. 3

Research Design 5

Definition of Terms. 7

Delimitations. 11

Limitations. 12

Organization of Thesis 12

II REVIEW OF RELATED LITERATURE. 14

Objectives Served by Laboratory Activity . 14

Conceptual Basis for Laboratory Activity . 16

Introduction. 16

Development of Scientific Process Skills 17

Providing Concreteness to Science Concepts 18

Teaching and Learning Science by Inquiry 19

Development of Scientific Attitudes . . 22

Dealing with Alternative Conceptions . .23

Phases of Laboratory Activity. 27

The Pre-Laboratory Phase 28

The Laboratory Phase. 30

The Post-Laboratory Phase 32

The Learning Cycle and Laboratory Activity Phases. 34

Interaction Dynamics in Laboratory Activities 37

Student - Student Interaction. 37

Teacher - Student Interaction 41

Student - Experiment Interaction 45

Impacts of Laboratory Activity 51

Attitudes Towards School Science 51

Understanding the Nature of Science. . .54

Developing Scientific Process Skills.54

Learning the Concepts of Science. . .55

Developing Scientific Attitudes . . .57

Summary and Implications of the Literature Review 58

III DESIGN OF THE STUDY 61

The Pilot Study. 61

The Main Study 65

Setting for the Study. 65

Data Collection Techniques 67

Researcher's Field Notes. 67

Photocopying of Investigations Observed and Students' Laboratory Reports 69

Administering Student Science Opinionnaire 70

Interviewing Teachers and Students . 73

Tape-recording of Pre- and Post-Laboratory Discussions 75

Science Laboratory Interactions Categories (SLIC) Checklist. 76

Procedure for Treatment of Data 78

Researcher's Field Notes 78

Laboratory Investigations Observed . 81

Student Laboratory Reports 82

Student Science Opinionnaire Data. . 83

Recorded Interviews 85

Recorded Pre- and Post-Laboratory Discussions 85

Science Laboratory Interaction Categories (SLIC) Data 86

Research Methodology 87

Means of Establishing Reliability and Validity. 88

Observer Bias 90

Ethical Issues. 92

Summary. 93

IV RESULTS OF THE STUDY. 96

Research Setting 97

Arfvedson Junior High School (Grade 7). 97

Chadwick Junior High School (Grade 8) .. 99

Aston Junior High School (Grade 9). . .101

Results Obtained 103

Laboratory Investigations Observed . .103

Analysis for Scientific Process Skills 105

Level of Inquiry 108

Student's Laboratory Reports. 110

Science Opinionnaire Response Data. . 114

Response Categories in Opinionnaire Data. 115

Responses to Question 30 122

Teacher Interviews 126

Student Interviews 136

Data on Pre- and Post-Laboratory Discussions. 150

Pre-laboratory Discussions 151

Post-laboratory Discussions. 153

Science Laboratory Interaction Categories (SLIC) Results 155

Researcher's Field Notes. 159

Summary 164

V DISCUSSION OF RESULTS 167

Organization of Laboratory Activities. . 167

Three Laboratory Phases 167

Level of Inquiry 170

Assembling of Equipment and Preparing of Materials. 174

Preparation of Lab Reports. 176

Student-Student Interaction During Laboratory Activities. 179

Student-Teacher Interaction During Laboratory Activities 182

Student-Teacher Interaction at the Individual Group Level 182

Dealing With Alternative Conceptions. 185

Student-Experiment Interaction During Laboratory Activities 188

Student Engagement in Laboratory Activities 188

Operation of Learning Cycle in Laboratory Activities 190

Impacts of Lab Activities From Teacher-Student Perspectives 192

Increasing Student Understanding . . 192

Motivating Students 194

Teaches Students How to Work With Each Other. 196

Affects Students' Attitude Toward Science 198

Summary. 201

VI SUMMARY, IMPLICATIONS AND RECOMMENDATIONS . . . 204

Summary of Data Collection and Analysis 204

Summary of Research Findings 206

Organization of Laboratory Activities At the Junior High Level. 206

Structuring of Laboratory Activities 206

Laboratory Activities are Composed of Three Phases 207

Amount of Laboratory Work. 207

Extent of Student Involvement. . . . 208

Extent of Student Interactions During Laboratory Activities. 209

Student-Student Interactions 209

Student-Teacher Interactions 210

Student-Experiment Interactions. . . 211

Impacts Attributed to Laboratory Activities 212

Cognitive Impacts 212

Affective Impacts. 213

Psychomotor Impacts 213

Process Impacts 214

Implications For Science Educators 214

With Respect to Organization of Laboratory Activities 214

With Respect to Student Interaction During Laboratory Activities 215

With Respect to Learning Outcomes of Laboratory Activities 217

Recommendations For Further Research. . . 218

BIBLIOGRAPHY 222

APPENDICES 230

A An Inventory of Processes in Scientific Inquiry 231

B A Scientific Process Skills Analysis Mode . . 235

C A Modified Version of Fisher's Science Opinionnaire. 238

D Science Laboratory Interaction Categories (SLIC) 244

E Characterization of an Inquiry Lesson Chart . 248

F The Three Phases of Laboratory Activity 250

G Summary of Researcher Field Notes 264

Field Notes for Grade 7. 265

Field Notes for Grade 8 269

Field Notes for Grade 9. 273

H Laboratory Investigations Observed 278

Grade 7 Investigations 279

Grade 8 Investigations 288

Grade 9 Investigations 294

I Analysis of Investigations for Scientific Process Skills. 302

Analysis of Grade 7 Investigations 303

Analysis of Grade 8 Investigations 315

Analysis of Grade 9 Investigations 323

J Edited Laboratory Reports of Three Selected Students. 335

Arfvedson Grade 7 Class. 336

Chadwick Grade 8 Class 343

Aston Grade 9 Class. 346

K Analysis of Opinionnaire Data 350

Analysis of Likert Items for the Grade 7 Class. 351

Analysis of Likert Items for the Grade 8 Class. 353

Analysis of Likert Items for the Grade 9 Class. 355

Summary of Edited Responses to Question 30 for the Grade 7 Class. 357

Summary of Edited Responses to Question 30 for the Grade 8 Class. 359

Summary of Edited Responses to Question 30 for the Grade 9 Class. 362

L Interview Questions 365

Student Interview Questions. 366

Teacher Interview Questions. 371

M Summary of Teacher Interviews 376

Pre-Laboratory 377

Laboratory Work. 381

Post-Laboratory 383

Scientific Processes 384

Level of Inquiry 385

Impacts of Laboratory Activity 387

Use of Other Instructional Methods. 391

Lab Exams. 393

Amount of Lab Work Done. 393

Example of an Interview Transcript 395

N Summary of Interviews with Selected Students . 399

Summary of Interviews with Students in Arfvedson School 400

Summary of Interviews with Students in Chadwick School. 409

Summary of Interviews with Students in Aston School 414

Example of an Interview Transcript 420

O Summary of Pre- and Post-Laboratory Discussions 423

Grade 7 Class Pre-laboratory Discussion 424

Grade 7 Class Post-laboratory Discussion 426

Grade 8 Class Pre-laboratory Discussion 427

Grade 9 Class Pre-laboratory Discussion 429

Grade 9 Class Post-laboratory Discussion 432

P Summary of SLIC Checklist Observations. . . . 434

Grade 7 Class. 435

Grade 8 Class. 436

Grade 9 Class. 437

Q Permission Letters 438

Student Permission Letter. 439

Copyright Permission Letters 441

LIST OF TABLES

TABLE PAGE

1 Student Scores on Split Halves-Odd Numbered and Even Numbered Statements of Opinionnaire (Pilot Study) 72

2 Student Percent Responses For Questions 21-29 of Modified Fisher's Opinionnaire (Pilot Study) 74

3 Summary of Analysis of Investigations Observed 106

4 Summary of Student Percentage Responses For Opinionnaire 116

5 Summary of Student Responses to Open-ended Opinionnaire Questions (#30) 124

6 Summary of Teacher Interview Responses For Nature of Laboratory Activity. 127

7 Summary of Teacher Interview Responses For Impact of Laboratory Activities. 134

8 Summary of Student Interview Responses For Nature of Laboratory Activities. 137

9 Summary of Student Interview Responses For Impact of Laboratory Activities. 146

10 Percentage of Observed Laboratory Time Spent by Selected Students in Each of the Science Laboratory Interaction Categories (SLIC) Over Several Investigations 157

11 Summary of Researcher Field Notes For Arfvedson School (Grade 7) Investigation 1 . 265

12 Summary of Researcher Field Notes For (Grade 7) Investigation 2 267

13 Summary of Researcher Field Notes For (Grade 7) Investigation 3. 268

14 Summary of Researcher Field Notes For Chadwick School (Grade 8) Investigation 1. . 269

15 Summary of Researcher Field Notes For Chadwick School (Grade 8) Investigation 2. . . 272

16 Summary of Researcher Field Notes For Aston School (Grade 9) Investigation 1 273

17 Summary of Researcher Field Notes For Aston School (Grade 9) Investigation 2 275

18 Summary of Researcher Field Notes For Aston School (Grade 9) Investigation 3 276

19 Analysis of Grade Seven Investigations Arfvedson Junior High School Investigation 1 303

20 Analysis of Grade Seven Investigations Investigation 2 307

21 Analysis of Grade Seven Investigations Investigation 3 311

22 Analysis of Grade Eight Investigations Chadwick Junior High School Investigation 1 315

23 Analysis of Grade Eight Investigations Investigation 2. 319

24 Analysis of Grade Nine Investigations Aston Junior High School Investigation 1 . . 323

25 Analysis of Grade Nine Investigations Investigation 2. 327

26 Analysis of Grade Nine Investigations Investigation 3 331

27 Analysis of Likert Items of Opinionnaire For Grade Seven Class. 351

28 Analysis of Opinionnaire Items for Grade Eight Class. 353

29 Analysis of Likert Items of Opinionnaire For Grade Nine Class 355

30 Summary of Edited Responses to Question 30 of Opinionnaire for Grade 7. 357

31 Summary of Edited Responses to Question 30 of Opinionnaire for Grade 8. 359

32 Summary of Edited Responses to Question 30 of Opinionnaire for Grade 9. 362

33 SLIC Checklist Observations Grade 7 Class. . . 435

34 SLIC Checklist Observations Grade 8 Class. . . 436

35 SLIC Checklist Observations Grade 9 Class. . . 437

LIST OF FIGURES

Figure Page

1 Illustration of Data Analysis Procedure 79

CHAPTER 1

INTRODUCTION TO THE STUDY

Science educators claim that school laboratory activities are central to students' learning of science. For instance, Ramsey and Howe (1969) state that "the experience possible for students in the laboratory situation should be an integral part of any science course . . . ." (p. 75). Shulman and Tamir (1973) indicate that "the laboratory has always been the most distinctive feature of science instruction" (p. 1118). This idea is further illustrated by Renner (1972), "at whatever grade level science is taught, the laboratory must be used and used not only to verify, but to find" (p. 328). Hellingman (1982) states, "teaching science nowadays includes more teaching of experimental methods than it formerly did, and this trend may well continue" (p. 29).

Although educators are expressing support for laboratory work in school science; researchers have not firmly established a complete picture of the effects laboratory activities have upon student learning. Hofstein and Lunetta (1982) in examining the literature for neglected aspects of research on the role of laboratory activities cite Watson (1978) as indicating that:

> Researchers have not comprehensively examined the effects of laboratory instruction on student learning and growth in contrast to other modes of instruction, and there is insufficient data to confirm or reject convincingly many of the

> statements that have been made about the importance and effects of laboratory teaching." (p. 212)

Leonard (1981) also in examining the literature on laboratory instruction cites Welsh (1980) as stating, "there is no convincing research evidence to support the value of laboratory instruction. Much that we try to do in the laboratory could be more easily and efficiently taught under a modified lecture format" (p. 445).

This does not indicate that laboratory work is not an essential means for student learning of science; but instead, that the value of laboratory activities has not been established for achieving many of the goals in science education. It may be that laboratory work is more effective in fulfilling some goals of science education than others, and that indeed it may be the major (or only) way of achieving some of them (e.g. developing skills in manipulating equipment and materials). Hofstein and Lunetta (1982) state that,"it is unreasonable to assert that the laboratory is an effective and efficient teaching medium for achieving all goals in science education" (p. 212).

With many junior high schools in Alberta presumedly using some laboratory activities to foster student learning, further research is required to understand this mode of teaching and learning science. Greater attention needs to be focussed on delineating the organization and strategies of school laboratory activities, and on identifying the learning outcomes that might be attributed to them.

After reviewing the recent research literature on laboratory work in science instruction, Gallagher (1987) commented that:

> Laboratory work is an accepted part of science instruction. Given its important place in the education of youth, it is surprising that we know so little about its functioning and effects. (p. 331)

Statement of Problem

This study is an examination of what science laboratory activity actually is at the junior high school level, and the learning outcomes attributed to it by participating students and teachers. Three general questions are used in guiding this study:

1. How are laboratory activities organized at the junior high school level?
2. What is the extent of interactions between student-student, student-experiment, and student-teacher during laboratory activities?
3. Which learning outcomes do students and teachers attribute to involvement in laboratory activities?

Importance Of The Study

The major contribution this study will have is to throw some light on the nature and effects of laboratory activities. Presently, science education literature only provides piecemeal descriptions of laboratory activity. Consequently, the reader is left with having to search through many reports to arrive at even a fragmented view of what is, or should be, involved in performing school science laboratory activities. When attempting to obtain a description of laboratory activity for a specific level of schooling (e.g. senior high school) the task of searching the literature becomes even more onerous.

The current study makes the contribution of providing the reader with a more comprehensive picture of what science laboratory activity is at the junior high school level. With this description laboratory activities can hopefully be understood as having distinct and unique characteristics which play an important role in the teaching of science. That is, by focussing upon the actual teacher and student experiences within laboratory instruction the stage is prepared for perhaps seeing the uniqueness of this instructional mode in fostering specific student learning. In addition, it should assist in defining with greater clarity the learning goals for which laboratory work is able to make important contributions.

With a description, in this study, of laboratory activity as an entity having continuity from its initiation to completion, the learning outcomes attributed to it perhaps will take on greater reality. That is, learning outcomes attributed by students and teachers to laboratory activity should be seen in relation to the actual laboratory activities performed rather than as an isolated list of possible outcomes. Perhaps, this will assist in indicating the uniqueness of some of the learning outcomes attributed to laboratory activities, and give additional credibility to the value of employing laboratory instruction.

Research Design

If teachers are using the laboratory in teaching science, they must feel that it is accomplishing something special for their students. What are the teachers justifications for doing lab activities? By analyzing the strategies and behaviors of teachers and students engaged in laboratory activities, a better understanding should be obtained of the role for laboratory activity in science education as practiced within contemporary schooling.

To determine the three dimensions of organization, interaction dynamics, and impacts of laboratory activity the following data collection approaches were used:

1. Observing and recording in field notes the primary aspects of the organization and dynamic of a total laboratory investigation, from initiation in a pre-laboratory discussion to the actual hands-on activity, to the conclusion in a post-laboratory discussion. In addition, tape recordings were made of the pre- and post-laboratory class discussions. Analysis of field notes made during observation sessions was done by coding the margin of each page with key phrases which expressed the action occurring. These phrases were used to note emerging

patterns in the laboratory activities. Analyzing data immediately after conducting each period of field work served to guide the observations for the next session. Similarly, recorded pre- and post-laboratory discussions were transcribed and from notations made in the margins of the transcriptions recurring patterns were established.

2. Taping interviews with selected students and their teachers, with the intention of obtaining individual viewpoints on the laboratory activity. Interviews were transcribed and analyses for emerging occurrences were made from notations made in the margins of transcriptions.
3. Obtaining laboratory activity documents. These included:

   (a) A copy of the laboratory activities on which students were currently working.

   (b) Photocopies of student prepared laboratory reports or segments of notes.

   These documents were examined for use of scientific process skills through a procedure developed by Nadeau (1984) (See Appendix B).
4. Requesting all students within the class to complete an opinionnaire in order to assist in determining their feelings toward laboratory activities. A modified version of Fisher's Opinionnaire (1973) was used (See Appendix C). Analysis of opinionnaire

responses was made by using weighting numbers assigned to statement choices by the researcher. These weightings were used in determining the percent responses for each choice.

5. Observing three selected students within the class to determine their interactions during laboratory activities by using "The Science Laboratory Interaction Categories (SLIC)" instrument, developed by Shymansky and Penick et al, 1979 (See Appendix D). The interactions of selected students were examined by converting all observed interactions in a given SLIC category into a percentage of observations made during the laboratory activities.

Experience was gained in using the data collection modes during a two phase pilot study with grade 9 science classes in three schools. On the basis of these experiences it was decided to conduct the main study with one science class in each of grades 7, 8, and 9 and over a time period of three weeks for each class.

Further description of the research design, including modifications resulting from the pilot study, is provided in Chapter Three.

Definition of Terms

1. Stated Curriculum in this study is the curriculum that students are to engage in as defined in a Department of Education program of studies and elaborated in its curriculum guide for junior high

school science. This curriculum advises that substantial emphasis be placed on laboratory work in junior high science.

2. A Laboratory Activity is considered to be a classroom learning experience in which students interact, with the teacher and each other, as well as with the laboratory experiment in the process of making observations and in attempting to determine explanations for scientific phenomena. These experiences can include sub-activities such as planning and designing an experiment, recording, observing, analyzing, interpreting and writing a laboratory report. A laboratory activity is considered to consist of three phases: pre-laboratory phase, a laboratory phase in which the students set up and manipulate materials and equipment, and a post-laboratory phase.

3. Dimensions of Laboratory Work for this study are the goals, organizational aspects, instructional components, modes of use (e.g. process skill orientation), learning experiences, role parameters, participant interactions, and so on, which are effectively fulfilled through science laboratory instruction.

4. Scientific Process Skills are defined as categories of activities practicing scientists may use during their research endeavors. In this study

the Inventory of Scientific Processes in Scientific Inquiry developed by Nay et al. (1971) is used (See Appendix A). Two categories of objectives for the processes are recognized: student cognition of the process skills and students using these in their investigations action. This study is primarily concerned with the action component.

5. Level of Inquiry refers to the degree of structuring and guidance given to students by teachers and laboratory notes or manuals in performing laboratory activities. This can range from a low level, in which students are engaged in verification or "cook-book" type of investigations, to a high level in which students are involved in problem identification and research type of investigations demanding creativity and original work.

6. Nature of Laboratory Activity refers in the study to the mechanics of initiating laboratory work and carrying it out efficiently and effectively. It relates to decisions made with regard to the design, scheduling, implementation, and supervision of laboratory work. This definition is also considered as containing the management of time allotted to laboratory activity, methods by which students are grouped, amount of teacher guidance provided, level of inquiry for investigations, time

allotment to each phase of laboratory activity, and preparation and maintenance of required materials and equipment.

7. Dynamics of Laboratory Activity are considered as encompassing interactions of students with teachers, students with students, and students with the science program while doing laboratory work. It includes those interactions occurring during all three phases of laboratory activity: pre-laboratory, laboratory, and post-laboratory.
8. Impacts of Laboratory Activity on Students refers to the effects that laboratory activities have on the motivation, learning, attitudes, and skills of science students.
9. Patterns for purposes of this study will refer to the characteristics and behaviors the various classes seem to have in common when engaged in laboratory activity.
10. Themes are defined as postulates which tie the various patterns identified in laboratory activities to give a holistic view. They serve as providing a relationship between patterns.
11. Participant Observer is one who comes to a social situation to engage to some extent in the activities of the situation and also to observe the activities, people and physical characteristics of the situation. In the present study I am acting as

a participant observer by being present during student laboratory activities to make observations, by participating mentally in student activities, and by interacting with some of the students during interviews.

Delimitations

1. The present study is not concerned with an assessment of the effectiveness of laboratory activities on learning outcomes. However, a qualitative identification of learning outcomes from the perspective of students and teachers will only be made.
2. This study does not attempt to determine the superiority of laboratory activity over other teaching methods on learning outcomes. In particular, no comparison will be made between the cognitive, affective and psychomotor development as produced by laboratory activities and other instructional methods.
3. The dynamics and strategies of instructional methods used in science teaching, other than laboratory work (e.g. lecture, notes, films, etc.) are not examined directly, even though some of them are incorporated in the three phases of laboratory work.
4. In this study measurements are not conducted to assess the degree to which instructional goals as specified by the program of studies are actually

being achieved.

5. Of the several modes of practical work possible in science teaching, only indoor (classroom) laboratory work was studied.

Limitations

1. This study is confined to laboratory activities as used at the junior high school level. Therefore, any direct implications for the senior high and elementary levels may be limited because of the uniqueness of each of these levels.
2. With the main study involving one class at each grade level within the junior high school setting, caution needs to be exercised when the reader attempts to generalize the findings to other junior high schools in Alberta where the circumstances may be substantially different.
3. The type, quality and amount of data gathered is limited by the modes of data collection used. Specifically, the videotaping of laboratory activities was tried in the pilot phase but the logistics involved and the analysis of video data was too daunting for this study. Undoubtedly, a good deal of valuable information was lost as a result of the decision not to use the video as a means of collecting data.

Organization of Thesis

This thesis is divided into six chapters and sixteen appendices which provide examples of instruments used in data collection and analysis, and include details of collected data in the form of charts and summaries.

Chapter 1 introduces the problem to be studied, indicates the importance of the study, outlines the research design used and defines terms which have particular relevance to the study. It also provides statements of delimitations and limitations for the current study.

Chapter 2 is a review of literature pertinent to the following aspects of laboratory activity: conceptual basis, organization, interaction dynamics, and impacts.

Chapter 3 outlines the design of the study including the pilot study, main study, and methods used for data collection and analysis.

Chapter 4 portrays the data collected while visiting the three school science laboratories, and then delineates the findings obtained by using each of the data collection techniques.

Chapter 5 presents a discussion of findings as provided with reference to the nature of laboratory activity, and impacts of laboratory activity.

The last chapter summarizes the findings of the study, outlines implications for science teaching, and makes recommendations for further research.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Over the past several decades many studies have been conducted on the impact of laboratory use in science teaching. Many of these were of a comparative type in which an attempt was made to determine the relative effectiveness of two or more methods of science teaching, one of them being the use of laboratory activity. These comparative studies are not dealt with exhaustively in this review. Instead, the literature is examined with respect to such dimensions of laboratory activities as: objectives, organization, interaction dynamics, and impacts.

Objectives Served by Laboratory Activity

Most, if not all, statements of objectives for science education issued by departments of education and education commissions imply a substantial use of the laboratory. For instance, in 1966 the Educational Policies Commission outlined the following values as underlying science:

1. Longing to know and understand.
2. Questioning of all things.
3. Searching for data and their meaning.
4. Demanding of verification.
5. Respecting of logic.
6. Considering premises.
7. Considering consequences.

Similarly, The Alberta Education Curriculum Guide for junior high school science (1978, p. 1-2) implies the need for use of laboratory activities in the following general objectives for science education:

1. To promote understanding of and development of skills in the methods used by scientists. This includes processes in scientific inquiry such as observing, hypothesizing, classifying, experimenting and interpreting data; intellectual abilities such as intuition, rational thinking, creativity, and critical thinking; skills such as manipulation of materials, communication, solving problems in groups and leadership.
2. To develop attitudes, interests, values, appreciations, and adjustments similar to those exhibited by scientists at work.

Teaching and learning of science differs from that experienced in most other school subjects. Many of the phenomena studied in science can be directly observed by students. Consequently, many science educators emphasize the importance of providing students with practical work where possible. Support for the latter statement can be cited from several relatively recent sources: Van Praagh (1983), Beasley (1985), and Hofstein and Lunetta (1982). Van Praagh, for example, states that "most science teachers would agree that a program for the study of science that did not include any practical work or experimentation would be travesty of a science education course" (p. 639).

Bates (1978) in reviewing the literature stated that laboratory activities are equal in effectiveness to lecture and demonstration teaching methods in transmitting science content. However, Bates also indicated that laboratory activities are more effective in:

1. providing students with skills in working with equipment.
2. nurturing positive student attitudes toward science.
3. teaching the process of inquiry when inquiry oriented activities are used.

Conceptual Basis for Laboratory Activity

Introduction

For laboratory work to be effective there needs to be a close connection between the stated curriculum objectives and the conceptual basis for performing laboratory activities.

For Lunetta and Tamir (1979) it is imperative that laboratory activities be selected to enhance teaching goals, and also to fulfill specified behavioral objectives of student learning.

> Generally, over the past two decades, science teachers have moved away from laboratory activities in which students merely illustrate, demonstrate, or verify known concepts and laws. Most educators now recognize the importance of developing the so-called 'higher' cognitive processes on which much of science is based - hypothesizing, predicting, and so on. Other goals thought important today involve developing attitudes and skills consistent with work of scientists and understanding scientific relationships, concepts, and models. (p.22)

This clearly indicates that laboratory activities need to be tailored in order to satisfactorily achieve the outlined teaching and student learning objectives. Why bother doing laboratory activities if they are not in some way assisting in the achievement of the goals as outlined for science education by provincial Departments of Education and Education Commissions?

According to Yager (1987) science is not just a body of specialized knowledge, but instead knowledge that arises due to scientific acts performed by scientists. Yager indicated that there are five domains of science: knowledge, processes, creativity, attitudes and applications. If students are to understand the nature of science then each of these domains needs to be considered in organizing for the teaching of science. With respect to laboratory activities a high level of inquiry would be required. Yager wrote, "studying science must therefore include exploring and observing with a questioning curious attitude, formulating questions, puzzles, and explanation of objects, phenomena, and ideas; then finally learning to communicate those explorations to others, to society" (p. 33).

Development of Scientific Process Skills

Ausubel (1978), Gagne (1963) and Klopfer (1971) are in agreement that during laboratory activities students should be provided with opportunities to learn and put into practice the scientific process skills. Ausubel (1978) expressed this by writing:

> The laboratory as a medium of instruction implies more than direct contact with and observation of objects and events. As differentiated from demonstration and observational exercises, it also involves discovery experience and concern with such aspects of the process of science as hypothesis formation and testing, designing and conducting experiments, controlling and manipulating variables and making inferences from data. (p. 376)

However, Ausubel (1978) and Schwab (1964) cautioned that laboratory activities developed for implementation of the processes of science, should not be considered as being independent of science subject matter within the course that students at a particular grade level are studying. Without subject matter the learning and application of scientific processes tends to become mechanical and meaningless for students. If students have been accustomed to using the scientific processes in this manner since kindergarten, then by the time they get to senior high school they should be capable of engaging in independent inquiry (e.g. problem solving) to some extent.

Providing Concreteness to Science Concepts

According to Gagne (1970) the learning of scientific concepts without employing of laboratory activities results in verbal superficiality, and memorization predominates as the approach used by students. This means that students do not really know or understand the scientific principles involved, and that there is a loss of connection to their real world experiences.

Further, in accordance with the Piagetian Model of Cognitive Development (Inhelder and Piaget, 1958) the stage of formal thought may begin in children at the age of 11 or 12 years and reaches an equilibrium state at about the age of 16 years, in some cases much later. Those children which have not reached formal thought processes, but are still in the concrete operational stage are unable to understand abstract concepts. However, Piaget also claims that children may be in one developmental stage in regards to one concept and in another stage with respect to another concept.

With a substantial amount of the junior high school stated curriculum based on understanding of abstract concepts, it seems desirable to use laboratory activities with this age group of students. In this way students are provided with the necessary concrete experiences for abstract thinking. This position is reinforced in two statements made by Hincksman (1973, p. 85):

1. The school laboratory is essential for teaching children who are at Piaget's concrete operational stage, that is usually upper primary and junior secondary pupils.
2. Laboratory demonstration or experiments are useful when teaching a difficult concept by reducing it from the symbolic to iconic or even the enactive modes of Bruner.

Teaching and Learning Science by Inquiry

Teaching and learning science by inquiry can range from the highly structured or verification laboratory exercises to open-ended student inquiry. Nay (1970) stated:

> The diversity of student abilities and educational objectives facing a science teacher can be achieved only by an equivalent diversification of instructional techniques and materials. Consequently, there is as much need for the highly structured experiment in science teaching as there is for problem solving and research. (p.22)

According to Nay (1970) a low level of inquiry is still occurring within laboratory activities which are highly structured or where the teacher is providing a great deal of guidance. However, Nay suggested that guidance and amount of instructional structuring of laboratory activities can gradually be decreased not only by grade levels, but perhaps within each unit of a course throughout the year. This allows the level of student inquiry to be gradually increased. The level of inquiry that is possible in science education is also dependent upon such factors as the teaching style and commitment of the teacher, the resources and time available, the previous experience in inquiry learning of the students, and class size.

Schwab (1964) classified the different extents of possible student engagement in laboratory activities as levels of inquiry. According to Schwab there are three levels of inquiry. In the first, or simplest level, students are given the problems and designs for investigations which they perform. At the second level the problem is stated but students have to develop their own design. While at the third level students are required to develop both their own problem and design to learn about a scientific phenomena. It is at Schwab's third level of inquiry where the greatest extent of active student involvement is needed.

Thompson (1976) found from a questionnaire given to sixth form science teachers in England that verification laboratory exercises (low level inquiry) were considered as best for fulfilling the following aims of practical work:

1. To prepare the students for practical examinations.
2. To give experience in standard techniques.
3. To verify facts and principles already taught.
4. To develop specific manipulative skills.
5. To develop certain disciplined attitudes.
6. To help remember facts and principles.
7. To encourage accurate observation and description.
8. To become able to comprehend and carry out instructions.
9. To elucidate theoretical work as an aid to comprehension.
10. To make phenomena more real through experience.

In an open-ended inquiry laboratory students can formulate their own problems for study, outline needed procedures, provide purposes, make predictions of results, relate their current investigation to previous work, collect data by experimenting, analyze and interpret collected data, suggest new investigations, and apply their findings to everyday situations. Through engagement of students in open ended inquiry they do not only learn science content, but also the methods of science. According to Nagalski (1980):

> Learning by inquiry, then, is concerned not only with confirming the outcomes of another's research, but also with the methods of research. Through inquiry, students are conditioned to think critically and creatively, and to generate their own conclusions based on observations they themselves collect. In effect, they become scientists themselves. (p.27)

Development of Scientific Attitudes

Presently, attitudes will be dealt with from a conceptual perspective, i.e. scientific attitudes. This is differentiated from student attitude toward science as a human discipline and school science which will be dealt with later under the heading of "Impacts of Laboratory Activity."

In a review of attitudes as related to science education Gardner (1975) separated these two categories in the following manner:

> Attitude toward science (e.g. interest in science, attitudes towards scientists, attitudes toward social responsibility in science) and scientific attitudes (e.g. open-mindedness, honesty, skepticism).

Kozlow and Nay (1976) elaborated upon scientific attitudes by indicating that students demonstrate open-mindedness when they:

-consider and evaluate ideas presented by others.

-evaluate evidence which contradicts their hypotheses.

-consider several possible options when investigating a problem.

-consider both pros and cons when evaluating a situation.

Similarly, students are said to demonstrate honesty when they:

-report observations even when they contradict their hypotheses.

-acknowledge work done by others.

-consider all available information when forming generalizations and showing conclusions.

With regard to scientific attitudes, Woolnough (1976) asked teachers to rank 20 aims of school laboratory work. It was found that they consistently ranked four aims as being most important. In order of importance these were:

-to encourage accurate observation and description.

-to make phenomena more real through experience.

-to develop a critical attitude.

-to promote a logical, reasoning method of thought.

Upon examining this study Gauld and Hukins (1980) wrote "these results suggest that not only is the development of scientific attitudes included among aims of science education but that it is one of those considered to be most important" (p. 139).

Dealing With Alternative Conceptions

Students come to science class with certain information about instructional concepts which they have acquired from their everyday experiences with the physical world. This prior acquired knowledge can be of benefit in learning scientific concepts in some cases, but it can also be a hindrance in other cases. In those cases where it is a hindrance, the everyday concept and the scientific concept may be expressed by the same term, but may not have the same meaning (e.g. power, work). In still other cases these preconceptions of students consist of only partial knowledge or have limited application.

According to Hashweh (1986) the task facing science educators is to "get the student who uses a certain alternative conception to interpret a certain phenomenon, to use the scientifically accepted conception in interpreting that particular phenomenon and, possibly, other phenomena as well" (p.230). However, this is not an easy task, since often in the past these alternative conceptions have served students adequately. Consequently, "these preconceptions seem to be resistant to change" (Hashweh, 1988 P.121), and even tend to be retained after student have received instruction pertaining to the concept. This means that students will only accept the scientific concepts instead of their preconceptions when they are "exposed to new experiences for which the preconceptions are inadequate" (Hashweh, 1986), (p.235). Laboratory activities are of particular importance here since the laboratory provides students with concrete experiences to which they can compare their preconceptions, and then determine if they are adequate or not. This is illustrated by Piaget (1976) asking a group of children to swing a ball attached to a string in a circle and then to release the string so that the ball would hit a target. When Piaget asked the children to describe the path followed by the ball after the string was released, they replied that it followed a straight line. This observations, however, is not in agreement with predictions made by some students for a similar hypothetical problem developed by McCloskey et al (1980), "30 percent of the subjects believed that the ball would follow a curved path..." (p.1140). Consequently, by engaging in the actual laboratory activity students were able to see that the observed path of the ball is in conflict with their preconceptions of its path.

Making observations in a laboratory which are contrary to student held preconceptions are often not sufficient to promote changes in student thinking. According to Driver and Easley (1978) "pupils have to comprehend the new theory and integrate previous experience into it" (p. 80). To facilitate this process Driver and Easley (1978) suggested the use of "informal communication in small groups" (p. 80). Laboratory activities allow for this integrative process during the pre-lab and post-lab phases. Within the pre-lab phase students could be required to predict the solution to the stated problem. After the laboratory investigation has been performed students could discuss the results, either with their peers or in a teacher led class discussion. If these results are contrary to expectations then a critical examination may reveal reasons for this occurrence. The teacher's role in the process of facilitating accommodation of new conceptions according to Posner et al (1982) is as "an adversary in the sense of a Socratic tutor" (p.226). Within this role the teacher asks students probing questions which make students think about their observations and also "confronts the students with the problem arising from their attempts to assimilate new conceptions" (Posner et al, 1982, p. 226).

It seems that alternative conceptions can be discovered in almost any age group of science students, including college and university students. Why haven't these preconceptions been rectified in earlier years of schooling? Hashweh (1986), in reviewing several studies, arrived at the following possible explanation.

> 1. Teachers are unaware of student preconceptions.
> 2. Evaluation methods do not capture preconceptions or assimilation of new knowledge into existing conceptions. This is indicated by the many studies reviewed previously that show that students pass courses with good grades yet retain their preconceptions.
> 3. Preconceptions are not addressed even when revealed by students' answers. Teachers are not critical of answers revealing preconceptions (pp. 237-238).

Laboratory activities by providing concrete experiences can serve the role of making teachers and students aware of existing student preconceptions. This statement is supported by the following literature citings:

> Labs are another way to prevent misconceptions. Teachers can maintain close contact with their students during lab activities. In this way teachers can intervene by asking probing questions, a way of continually assessing their students' knowledge. Our finding that older students tend to conceal their ignorance by using scientific terms is motivation for teachers to make frequent use of questioning and formal and informal interviewing as they evaluate student progress. (Stepans et al., 1986, p. 68).

Fredette and Lochhead (1980) in providing 24 students, enrolled in introductory university physics courses, with simple electrical circuit exercises found that some students had difficulties with the circuits because of preconceptions, and consequently stated that:

> Perhaps we ought to heed the passing remark made by one student who was struggling with another simple bulb-and-battery circuit after having already completed a standard level electronics laboratory on R.C. filters. "We ought to do things like this in the lab." (p. 198)

Phases of Laboratory Activity

Laboratory activities may be organized into three distinct phases: pre-laboratory, laboratory work, and post-laboratory. Since much of the discussion below is based on a document prepared by Nay (1986), it is included in Appendix F.

In each of these three phases of laboratory activity definite tasks need to be completed by students and teachers. During the pre-laboratory phase tasks are completed which involve arranging for materials and facilities, and preparing students for performing of investigations. In the laboratory phase students are assigned those tasks which are associated with performing investigations, while teachers deal with tasks involving supervising and managing student laboratory work. For the post-laboratory phase student tasks are related to organizing and interpreting collected data, preparing reports, and participating in post-laboratory class discussions. Teachers are concerned with post-laboratory tasks connected to evaluating student laboratory reports and discussing performed laboratory investigations in class.

The pre-laboratory phase. The pre-laboratory phase allows the teacher and students to prepare for performing of the laboratory investigations. Often this requires that the teacher and students do advance preparation outside of class time. This additional preparation allows the laboratory work phase to progress more smoothly.

During the in-class part of this phase the class usually meets in a large group setting wherein the teacher generally plays the dominant role, particularly for low level inquiry investigations. Its purpose is to prepare learners for the laboratory work which is to follow. Consequently, teacher activities can include:

1. Motivating of students.
2. Identifying of apparatus and materials.
3. Clarifying of the problem and experimental design.
4. Familiarizing students with needed concepts and required precautions.

5. Revising of procedures to match availability of equipment and materials.
6. Demonstrating use and care of apparatus and needed techniques.
7. Dealing with student questions and difficulties regarding the pre-laboratory work.

Nay (1986) examined the three phases of laboratory activity with respect to tasks performed by teachers and students. The pre-laboratory phase is divided into three sections: teacher planning and preparation, student preparation for laboratory work, and in-class activity. The student in-class activity can include performing the scientific process skills previous to collection of data, i.e. identifying a problem, preparing background information, predicting, and designing the collection of data. While the teacher in-class activity can consist of discussing with students safety precautions, difficulties encountered in preparing for lab work, and follow-up activities to the laboratory phase. (See Appendix F).

According to Tamir (1977), "the time devoted to the pre-laboratory phase appears to be positively related to the complexity of the task and negatively related to the availability of previously prepared guidelines" (p.313). This means that the pre-laboratory phase for open-ended inquiry or problem solving may necessitate that the teacher give more time to assisting students, initially at least, in activities such as:

1. Identifying and formulating a problem.
2. Becoming acquainted with sources for background information and required theories.
3. Reviewing the required scientific process skills.
4. Outlining safety precautions and handling of hazardous materials.
5. Preparing an experimental design.
6. Understanding the care and use of special equipment which may be needed.

The laboratory phase. In this phase students carry out the investigation, make and record their observations. For the teacher this phase means supervising, managing and perhaps evaluating students as they do hands-on activities in the laboratory.

During the laboratory phase students are essentially involved, individually or in groups, with manipulating apparatus and/or materials, making quantitative as well as qualitative observations, and recording their observations. Consequently students perform activities such as:

1. Gathering needed equipment and materials.
2. Constructing and assembling required apparatus.
3. Rereading and studying the design as provided in structured investigations.
4. Washing provided glassware.
5. Measuring out amounts of materials as indicated in the design.
6. Mixing required chemicals to produce needed solutions,

mixtures, or compounds.

7. Setting up required glassware, and putting into motion required equipment (e.g. lighting bunsen burners, filling burets, turning on light sources, etc.)
8. Making and recording observations.
9. Taking down assembled equipment.
10. Washing and putting away used equipment.
11. Cleaning up their laboratory stations.

If the laboratory activities entail problem solving or problem identification and research (unstructured investigations) then specific segments of planning or initiation, such as developing an experimental design by trial and error, will also be included in the laboratory phase along with data collection.

As students are actively involved in performing the laboratory investigation teachers are usually occupied with supervisory kinds of activities. Nay (1986) delineated the teacher duties as supervising, guiding, managing and evaluating the laboratory work. Some tasks included in the teacher duties are: maintaining proper student discipline, helping students with difficulties, checking on student techniques and recording of data, and assessing the achievement of laboratory objectives.

For laboratory investigations with a high level of inquiry additional activities are required of the teacher. While involving students in the modified ALCHEM 30 experiments, which required a higher level of inquiry, Nadeau (1984) found that the teacher was also involved in activities such as:

1. Observing pupils to see if they were following their own designs.
2. Finding of equipment, materials, reagents, etc. for students who had changed their design.
3. Attempting to minimize all possible hazards.
4. Checking if students had realized any mistakes they may have made.

Tobin (1990) in reviewing the literature on laboratory activity research concluded that:

> The teachers' most important role is to facilitate learning by maintaining an environment in which students can make sense of what they are doing and receive challenges and assistance as required. Yet most teachers seem to be preoccupied with management in laboratory activities. (p. 414)

The post-laboratory phase. In this phase students are expected to process and interpret collected data, and to prepare laboratory reports or notes. It gives teachers the opportunity to evaluate student reports and to discuss completed laboratory investigations in class.

During the post-laboratory phase students are performing tasks such as:

1. Making graphs of tabulated data.
2. Doing mathematical calculations.
3. Interpreting graphed data or mathematical calculations.
4. Deriving inferences from processed data.
5. Calculating percent error and providing explanations

for discrepancies.

6. Discussing results with other classmates.
7. Formulating answers to provided inference questions.
8. Evaluating adequacy of the predictions, experimental design, and their technological skill in performing the investigation.
9. Determining the adequacy of generalization, law, or theory used in making the prediction.
10. Participating in post-laboratory class discussions.

Tamir (1977) portrayed the importance of the post-laboratory discussion, particularly in high level inquiry by saying:

> An inquiry-oriented laboratory leads to a post-laboratory discussion which is required in order to draw meaningful conclusions and to relate them to an appropriate conceptual framework. (p. 313)

However, often after marking students' laboratory reports or responses to a series of laboratory notebook questions, post-laboratory discussions are dispensed with. Tamir and Lunetta (1978) exposed this neglect in their examination of the Biological Sciences Curriculum study (BSCS) Textbook.

> Unfortunately, no specific guidance is given about post-laboratory discussions. Though many teachers use the results of laboratory work for discussion, many others may assume that the students' written responses to the many questions in the laboratory exercises are sufficient. Often teachers feel too pressed for time to conduct post-laboratory discussions. Unless the laboratory instructions provide explicitly for such discussions, much of the potential value of inquiry-oriented laboratory work may be lost (p. 354).

This same concern was reiterated by Lunetta and Tamir (1981) when they analyzed laboratory exercises in the Project Physics and Physical Science Study Committee (PSSC) physics courses. They stated that "explicit provisions do not exist for post-laboratory discussions to facilitate consolidation of findings and understanding" (p. 641).

Nay (1986) identified two aspects of teacher duties involved with the post-laboratory phase: specifically, class discussions and evaluation. Some of the teacher tasks for these two aspects are: discussing marked laboratory investigations in class, discussing questions posed in a laboratory manual, discussing discrepancies between student results and expected results, providing further explanations for difficult concepts, finding everyday applications of concepts, relating concepts to previously learned concepts, providing additional practice homework problems if necessary, and preparing and administering laboratory tests.

The learning cycle and laboratory activity phases.

The learning cycle according to Renner, Abraham, and Birnie (1988) is "a method of teaching - it is also a curriculum organization principle and is derived directly from the mental functioning model invented by Piaget" (p. 39). It was identified as the learning cycle approach in the Science Curriculum Improvement Study (Atkin and Karplus, 1962).

Three distinct phases are considered as composing the learning cycle:

1. The first phase is called exploration. This phase is "to allow students to experience the concept to be learned before language or other identifying labels are attached to it" (Renner, Abraham and Birnie, 1985, p. 303). During this phase students collect data by using actual material. Sometimes this data collection process "may be highly structured by the teacher or on other occasions relatively free, then the learner encounters new information which does not fit his existing structure" (Renner and Lawson, 1973, p. 168).
2. The second phase is known as conceptual invention. In this phase "the students, under the guidance of the teacher, combine their ideas, datation collection process "may be highly structured by the teacher or on other occasions relatively free, then the learner encounters new information which does not fit his existing structure" (Renner and Lawson, 1973, p. 168).
3. The third phase is referred to by titles such as: concept application, discovery, introduction of the concept, and expansion of the idea. Within this phase students are required to make use of the concept introduced during the conceptual invention phase. "They might engage in additional laboratory

activities, solve problems, answer questions, pursue individual investigations, and/or read about the uses of and further descriptions of the concept" (Renner, Abraham, Birnie, 1985, p. 651). This last phase can serve to give students experience in applying the newly acquired concept, principle, etc. to new applications, reinforce what was already learned, or provide additional practice for those having difficulty understanding the new concept or principle.

Can the learning cycle be operative within laboratory activity phases? The answer seems to be 'yes', but the laboratory investigations used, according to Renner, Abraham and Birnie (1985, p. 651), must meet the following criteria:

1. The students should not be informed what the concept to be learned is before the investigation is begun.
2. The student should not be able to discern the concept by merely reading the investigation's directions.
3. Using the investigation's directions must produce data which, when interpreted by the students and the teacher, will allow the concept to be identified and understood.
4. The investigation's plan must provide opportunities for the students to use the concept after it has been identified.

This seems to indicate that the laboratory activity phases must also meet certain criteria, if they are to be congruent with the learning cycle approach. These seem to be implied in the following statements:

1. The active experimentation experienced in the learning cycle is not the verification laboratory often encountered (Renner, Abraham, Birnie, 1985, p. 322).
2. Thoroughly explaining a concept before providing experiences with materials results in little or not conceptual understanding (Renner, Abraham, Birnie, 1988, p. 56).
3. Explorations which produce data need to be followed by discussions - conceptual inventions (Renner, Abraham and Birnie, 1988, p. 56).

Interaction Dynamics in Laboratory Activities

A study of the dynamics of laboratory activities comprises an examination involving interactions of students with: fellow students, teachers, and the science laboratory program. In essence it is what goes on, either because of design or voluntarily, while students are engaged in school science laboratory activities.

Student-Student Interaction

Students generally interact extensively with each other during laboratory activities. Usually in a laboratory setting students are grouped because of limited availability of laboratory facilities, equipment, and materials. Grouping students can often be beneficial since they can assist and learn from each other while performing their laboratory activities. Grouping also facilitates student-student interactions. This means that the individual is affected by his or her participation in a particular laboratory group, which may be composed of up to three or four members. Similarly, the lab group is changed by the presence of each of its members. Placing students in groups may have negative as well as positive effects. Hurd and Rowe (1966) illustrated possible negative effects by citing the following example:

> We may note that the behavior of our student changes after he enters the group. He refuses to work regularly: he is often argumentative; other members of the group address an increasing number of negative communications to him. (p.67)

Not only do the individuals in a laboratory group have an influence upon each other but sometimes they can have a bearing upon all other groups in the laboratory. This can occur because of their good or bad behaviors influencing others, or through results they have, or have not, obtained while performing their investigations. This means that happenings within a lab group have bearing upon learning outcomes for individuals in the group, the group as a whole, and the entire class. Hurd and Rowe (1966) portrayed this with results of the following study:

> Observations of BSCS laboratory groups in four high schools for two years indicated that while most groups operated smoothly, every classroom had some incidence of groups that seemed to suffer from organizational problems severe enough to cause delay in the completion of tasks. The incidence of groups with such problems varied from 15% in some classrooms to 50% in other classrooms. While smooth working units delegated and sequenced

> tasks effectively, as indicated by their low rate of error and the time-to-completion of experiments, groups with organization problems consumed working time trying to delegate tasks and clarify procedures. (p. 67)

Johnson (1981) concluded that "while the teacher-student relationship has traditionally been emphasized in American schools, there is considerable evidence that student-student relationships may be more important determinants of educational success" (p. 9). He outlined nine propositions which show the influence of student-student interaction for achievement of educational goals. Two of these propositions appear to have relevance to group work in junior high school science laboratory activities:

1. Peer relationships influence educational aspirations and achievement:

> Peers have a great deal of influence on students' educational aspirations and actual achievement. Especially when students are young and when they have poor study skills, interaction with academically motivated peers can significantly increase achievement. (p.6)

2. Peer relationships influence attitudes toward school:

> In order for peer relationships to be constructive influences, they must promote feelings of belonging, acceptance, support, and caring rather than feelings of hostility and rejection. In order to promote constructive peer influences, therefore, teachers must first ensure that students interact with each other and second must ensure that the interaction takes place within a supportive and accepting context. (p.6)

Consequently, it appears that interaction experiences with peers in laboratory groups can have an influence on students' attitude toward school, science and laboratory activities, and on their achievement in science.

Abraham (1976) attempted to determine if placing students in small groups according to their potential for divergent thinking would affect the kind and amount of verbal interaction between students during scientific inquiry. It was concluded that "homogeneous grouping is an effective way of encouraging greater amounts of valuable verbal interaction" (p. 134). Perhaps, it can also be said that placing students in homogeneous laboratory groups may allow for efficient performance of laboratory activities, development of positive attitudes, and better achievement.

A study of student interactions in laboratory settings conducted by Tobin (1986) through observing and interviewing 15 Western Australian high school teachers, and 86 students (45 males and 41 females) revealed the following:

1. Twenty-one of the male students indicated that they were active group members during the laboratory investigations, compared to 14 females indicating that they were active members. Alternatively, seven females reported that they usually were inactive group members as compared to four males indicating being inactive.
2. 90% of the students interviewed said that disruptive behaviors occurred during laboratory

activities. 24 of the 86 students interviewed reported extreme levels of off-task behavior and 29 of them reported moderate disruptiveness.

3. Off-task discussions between laboratory group members usually occurred as data were being collected, when group members did not understand what was required of them, and when they had completed the investigation before the allotted time period.
4. Disruptive off-task behaviors often involved misuse of laboratory equipment, or students physically interacting with others as they moved around in the classroom.

Teacher-Student Interaction

It seems that the basic tasks of teachers in laboratory-centered learning are to select appropriate learning tasks, provide the required setting, and to ensure that students are engaged in an appropriate manner. To achieve these basic tasks, however, requires effective teacher-student interaction. Stawinski (1986) expanded on the first two basic tasks by indicating that the teacher is involved in: informing students of the sequence of activities to be followed, planning the activities, and providing students with the required explanations and demonstrations to perform the planned laboratory investigation.

An expansion of the third basic task and an exemplification of the teacher-student interactions required is given by Darlington (1986):

> Don't try to evaluate students' laboratory performances during regular laboratory periods. Students must see you during these periods as an aide rather than as an evaluator. Move around always alert to help prevent unsafe practices, to pass on helpful suggestions and to answer questions. (p. 31)

Tobin (1986) also reiterated this by concluding that "as teachers move from group to group it is necessary to monitor the engagement of students within the group in a diagnostic sense and at the same time to monitor the behavior of the class as a whole in a managerial sense." (p.211)

An important question for hands-on science programs is, how does teacher interaction with students during laboratory activities affect student performance? Shymansky and Penick (1982) showed from the results of five studies, conducted in K-8 settings, that students can stay on tasks with inquiry type laboratory activities without highly directive and prescriptive teacher intervention. They found that non-directive teacher behaviors can improve the performance of students. Apparently students respond positively to the increased freedom and responsibility for doing their own work:

> Not only were students able to stay on-task with the hands-on activities as indicated by their 90% involvement rate, but special data collected during one-to-one teacher-student interactions revealed that students appear to stay on-task more when the teacher interacts less! Instead of stimulating further activity and investigation

> with the science materials, the data suggest that the teacher's interactions with students actually sometimes may have a stifling effect. (pp. 417-418)

Beasley (1983) studied the management behaviors of teachers during small group science laboratory activities, with junior high school students, by obtaining a continuous video record of student and teacher interactions. He observed that student performance was better when the teacher's attention was directed toward all members of the class, rather than toward one small group of students within the class:

> The results suggest that teachers who operated more at the whole class level have classes with a higher degree of task involvement. The data suggest that this task involvement may have been associated with teacher initiated interactions of a verbal kind which were for whole class attention. The data suggest that observation of the pupil activity was directed at the whole class from suitable positions throughout the laboratory, and this teacher behavior was associated with a higher task involvement of pupils. (p. 717)

Although Shymansky and Penick (1982) and Beasley (1983) advocated reduced teacher dominance and increased student responsibility during small group inquiry laboratory activities, it appears that there are definite limitations and restrictions to this reduction. For instance, it is often necessary for group members to request teacher clarification of procedures, or assistance in assembly of apparatus. Student laboratory activities seem to require teacher-student interaction even though that interaction is not teacher initiated. This particularly applies with students inexperienced in laboratory processes and techniques. Oakley and Crocker (1980) discovered that in elementary science laboratory groups, involving grades two, four and six, the pupils initiated half of the interactions between the teacher and themselves. However, Oakley and Crocker indicated that teachers still were essentially in control of the time spent with each group:

> Although the fact that pupils initiated about half the interventions seems to suggest a relatively high degree of pupil control of teacher time, this result must be interpreted in light of the fact that each class consisted of some 15 groups and that simultaneous requests for teacher attention by several groups were common in the classes. Under these conditions the teacher must often ignore some requests while attending to others. (p. 417)

Shymansky (1976) examined the relationship between length of teacher-student interaction during inquiry laboratory activity and the effect it has upon student behavior. If teacher-student interaction has importance in laboratory work, then it seems desirable to have an awareness of the effect of these interactions. Shymansky reported that teacher-student interactions "in fact may be construed by the student as interference if the interactions proceed too long" (p.257). Consequently there could be a reduction in work completed and learning effectiveness.

To determine the behaviors of teachers and students during laboratory activities, Shymansky and Penick (1979) prepared the "Science Laboratory Interaction Categories" (SLIC) instrument. It has been used extensively in assessing the performances of students and instructors in college science laboratories. During a field test of SLIC, involving observations of 30 laboratory instructors and 331 students, the primary student-instructor interaction characteristics portrayed included the following:

1. A large proportion of the time was used in transmitting information to students, in some cases as high as 56% during introductory classes.
2. More time was given to telling students answers than listening to student questions and comments about the laboratory activity. The maximum time given by instructors to listening to students was 18%.
3. A maximum of 14% of the time was spent in demonstrating procedures to students.
4. As much as 14% of the time in introductory laboratories was given to non-lesson related behavior, such as, idle conversation with other students.

Student-Experiment Interaction

The degree of student interaction with the science laboratory experiment is likely dependent on a number of variables including: teacher and pupil behavior, student grouping, attitude and interest of students, and type of learning tasks which are provided. However, the design used in developing learning tasks can be considered as a major determinant of student involvement in laboratory activities. In particular, the level of inquiry (that is, the degree of guidance or structuring of laboratory activities by teachers and/or instructional materials) definitely can influence the extent to which students are actively participating in laboratory investigations.

Nadeau (1984) developed an instrument (Appendix B) to determine whether a scientific process in an investigation was initiated by the student, or whether guidance was provided by the teacher and/or laboratory manual (the original ALCHEM 30, as well as Nadeau's revision of it). A section for researcher comments was also provided. In addition, it indicated totals for the scientific processes initiated by the students and for all the scientific processes utilized in the investigation. Nadeau assumed that the level of inquiry of an investigation was related to the percent of student-initiated process skills in it. With this instrument Nadeau showed that there was student growth in using scientific process skills as the level of inquiry was increased with the revised ALCHEM 30 laboratory investigations. He also found that most of his students enjoyed doing experiments with a high level of inquiry.

Tamir (1977) recorded both teacher and student behaviors, in 60-second intervals, while engaged in the three phases of laboratory activity. His investigation showed that teacher guidance in using scientific processes during pre-lab and post-lab discussions tend to change with grade levels of students:

> The teacher was much more directive in the ninth grade, less so in the tenth grade, reaching a low of 9% (of pre-lab time) in the eleventh grade. A similar trend may be seen regarding the post-lab phase. While the teacher in the ninth grade dominated this phase, student initiative gradually increased so that by the eleventh grade, about two-thirds of the post-lab was dominated by student activities. (p. 313)

A study by Tobin (1983) with 452 pupils from 15 classes, at the sixth and seventh year of schooling in Perth, Australia, indicated the relationship between teaching mode and degree and kind of student engagement in laboratory activities. The typical teaching mode teachers utilized was that of assigning students to small groups for data collection, but the whole class setting was used in planning of investigations and in processing of collected data. Three categories (covert, overt and off-task) were used in determining the type of engagement of students in investigation planning, data collection, and data processing. Tobin (1984) refers to Bloom (1980) as defining overt engagement as student participation which can be directly observed. For instance, "overt engagement might involve discussion, manipulation of materials, writing, drawing, or graphing" (Tobin, 1984, p. 470). Bloom (1980) defined covert engagement as thinking in relevant ways about what is going on in the classroom. According to Tobin (1984), "if student task involvement is covert, participation must be inferred by an observer" (p.

470). This type of involvement occurs "as students attend to the teacher during instruction, contemplate the plan of an investigation, or consider how a graph is to be interpreted" (Tobin, 1984, p. 470). The category of off-task occurs when students are observed as engaging in behaviors which are not related to the planned activity. With this organizational arrangement the following percentages for student engagement during laboratory activities were indicated:

Phase	Engagement type		
	Covert	Overt	
Off-task			
Planning	72	16	12
Data Collecting	5	80	15
Interpreting	66	21	13

Tobin (1984) observed 13 classes of Australian students to compare the proportion of time allocated to specific process skill learning tasks by their teachers, to the students' actual engagement in these tasks during laboratory activities. He found that student engagement rates varied with managerial strategies of the teacher. Consequently, he determined the mean percent for both the teacher lesson time allocation to specific process tasks and for the actual student engagement in these tasks. In his study teachers of grades six, seven, and eight allocated an average of approximately 93% of laboratory activity to required science process tasks and about 7% to off-task behaviors (behaviors of students that are not directed at achieving designated tasks). However, the actual engagement of students was approximately 63% and the off-task behaviors 37%. This study indicated that students primarily only became actively involved during data collection and processing of data, even though teachers planned for, and allotted, adequate time for active student involvement during the planning of the investigation. It also indicated that a much greater amount of time is spent in student off-task behavior during laboratory activities than teachers anticipated.

Lunetta and Tamir (1979) have indicated that laboratory activities should be selected in order to enhance particular teaching goals. Consequently they listed 24 process skills, related to scientific inquiry as found in a review of the literature, and showed that these can be used as a checklist to analyze individual investigations or entire laboratory notebooks to determine the degree of student involvement in using the scientific processes. For purposes of their checklist they grouped the scientific processes under four headings which represented four different phases of laboratory work: planning and design, performance, analysis and interpretation, and application. By analyzing numerous laboratory handbooks with this instrument Lunetta and Tamir found that students "are given few opportunities to discuss sources of experimental error, to hypothesize and propose tests, or to design and then actually perform an experiment" (p. 23). This is further illustrated by the instrument being used to analyze Experiment 12, "Centripetal Force" in Project Physics. It was indicated that this laboratory investigation lacked activities relating to student planning and design. Based on the information from this type of analysis the teacher is better prepared to determine if the investigation should be used as is, or if modifications are needed to have the investigation meet the teacher's goals for laboratory learning, e.g. greater student engagement in the laboratory activity.

Okebukola (1985) explored the relationship between laboratory behavior strategies of students, performance, and attitude toward laboratory activity of 600 students in Nigeria. Three instruments were used in the study. The Shymansky and Penick, et al (1979) SLIC checklist was used to assess student behavior strategies. Performance was determined by observational assessment of students using laboratory practical skills. An attitude to laboratory work scale was used to find student attitude toward laboratory activity. It was found from the study that the SLIC student behavior categories of "manipulates apparatus" and "actively observes experiment" had high correlations with acquisition of practical skills and attitude toward laboratory activity, while the SLIC student behaviors of "transmitting information," "listening," and "non-lesson related behaviors" had low correlations with acquisition of practical skills and attitude toward laboratory activity. Okebukola concluded that the findings support the view that students best acquire process skills while interacting actively with hands-on laboratory activities.

Impact of Laboratory Activity

The impact of laboratory activities is reviewed with respect to: student attitudes toward school science and laboratory work, and understanding of nature of science. Development of scientific process skills, learning of scientific concepts, and developing of scientific attitudes will be included under the heading of understanding the nature of science.

Attitudes Towards School Science

It is obvious that students should develop positive attitudes if they are to receive maximum benefit from their science education, and if science is to be used by them in the future. Charen (1966) reinforces this by stating:

> Their experience in the classroom and the laboratory should provide challenge, enjoyment, and satisfaction. Such attitudes are significant in the general education of students as well as for those who chose science as a vocation. (p. 56)

Support for attitude development in laboratory settings is also given in studies conducted by Hofstein et al (1976), Raghubir (1979), and Nadeau (1984). They found that students generally enjoyed laboratory work and that it affected their attitudes and interests in science. Johnson, Ryan and Schroeder (1974) compared groups of students who learned science in three different ways:

1. From a textbook.
2. By using a textbook and laboratory materials.
3. Performing only laboratory activities.

It was found in this study that those students who were involved in laboratory activities in some way had significantly more positive attitudes toward learning science than those who learned science by only using a textbook.

Fisher (1973) developed a science attitude opinionnaire, and administered it to some grade seven and eight students in the United States. The results indicated that generally students at these two grade levels felt that doing science experiments was enjoyable, and that much was learned by doing them.

When McMillan and May (1979) asked junior high school students the question "think about classes you've had in science, what things did you like best"? They found that "seventy percent of the students indicated that they liked experiments, investigations, dissecting, and other hands-on activities best" (p. 129). Accordingly, laboratory activities can have a strong influence upon students' development of positive feelings and interests in science.

Denny and Chennell (1986) interviewed English students from the first four years of a mixed comprehensive school, to determine their attitudes and views toward laboratory activity in school science. The interviews revealed that laboratory activities:

1. Teach you to handle and use things accurately and carefully.
2. Help you to make discoveries and to find out new things.
3. Teach you to handle scientific equipment.
4. Help you test an idea to see if it is right.
5. Help you remember what you have already learned.
6. Break up lessons and so make them more interesting.
7. Teach you how to go about solving problems.
8. Gives you courage and willingness to try to solve problems.

Similarly, Bryant and Marek (1987) asked some Oklahoma teachers and students to reveal their feelings toward the laboratory-centered approach to teaching science. These two groups identified quite similar advantages for doing laboratory activities. Included were the following:

1. Involves students in the learning process and makes class enjoyable and stimulating.
2. Produces deeper understanding.
3. Requires individual thinking skills.
4. Makes science relevant and meaningful.

Simpson and Oliver (1985) examined differences in male and female attitudes toward science. Their study included approximately 4,000 students, grades six to ten, in a large school system from central North Carolina. They found that:

1. Males showed a significantly more positive attitude toward science then females. This was generally true at all grade levels.
2. Female students were significantly more highly motivated to achieve in science than were the males. This was found to be so at each grade level.

In general, this study also reported that there was a decline in attitude toward science and motivation to achieve in science for adolescent students, and that there was a significant gender difference.

Understanding the Nature of Science

The literature relating to the nature of science will be provided under three subheadings: developing scientific process skills, learning the concepts of science, and developing scientific attitudes.

Developing scientific process skills. Yager, et al. (1969), Klopfer (1971), Doran (1978), and Lynch and Ndyetabura (1983) concur that students who experience science by engaging in laboratory activities tend to develop skills in:

1. Using common laboratory equipment.
2. Performing common laboratory procedures and techniques.

Consequently, laboratory activities can be considered as being particularly appropriate for development of behaviors within the psychomotor area.

Blosser (1988) indicated that laboratory activities may not be the most efficient means of teaching students scientific facts. But, Blosser also stated that "with its emphasis on sensorimotor experiences through hands-on activities, laboratory work is more likely to facilitate observation and manipulation skills" (p. 57). Several other skills must be employed by students in conjunction with manipulative skills in order to carry out laboratory activities. Sund and Trowbridge (1967) developed a list of such skills and Blosser (1988) gives recognition to them:

1. Acquisitive skills - such as listening, observing, gathering data.
2. Organizational skills - recording, classifying, organizing data.
3. Creative skills - planning ahead, designing a new problem or approach, inventing, synthesizing.
4. Communicative skills - asking questions, discussing, explaining, reporting, writing, graphing.
5. Safety skills - handling equipment and potentially dangerous chemicals with care.

Learning the concepts of science. Nadeau (1984) modified the ALCHEM 30 experiments to allow for an increasing degree of student inquiry and a diminishing of teacher and laboratory manual guidance and direction. Nadeau's students learned to handle process skills, including high level of inquiry (his last investigation was at the problem identification level). By using both quantitative and qualitative data collecting techniques to study the effects of this increased level of inquiry, Nadeau arrived at the following conclusions:

> 1. Students can become independent inquirers in a laboratory program.
> 2. Emphasis on inquiry-oriented laboratory work need not penalize student achievement on external exams in which only the conceptual domain is evaluated.
> 3. Students are more motivated to work in an inquiry program because they find it more interesting and challenging.
> 4. Students engaged in a chemistry course with emphasis on inquiry-oriented laboratory activity gain a better understanding of and feeling for the nature of chemistry than is provided by a didactic teaching approach. (p. 177-178)

Kruglak and Wall (1959) also agreed that students which engaged in laboratory activities were not at a disadvantage in learning scientific concepts. In reviewing the results obtained in earlier studies (1952-53) with respect to physics laboratory activities, Kruglak and Wall stated that:

> Students who got laboratory instruction by the individual or demonstration method were superior to students without any laboratory instruction on the three tests designed to measure laboratory achievement. However, no significant differences between the laboratory groups and the no-laboratory group were found for the theory tests. (p.153)

Kerr (1963), and Nedelsky (1965) in identifying objectives fulfilled by laboratory activity included "elucidating the theoretical work so as to aid comprehension". By being involved in hands-on activities the scientific concepts become easier for students to understand, since they experience contact with reality in dealing with the actual materials and equipment. This is reinforced by Lehman (1989) conducting a study with 1570 high school chemistry students and 295 chemistry teachers in the United States, to determine their perceived advantages and disadvantages of chemistry laboratory activities. He found that:

> Both teachers and students most frequently perceived cognitive advantages of laboratory activities. The notion that laboratories help students understand the abstract concepts and principles introduced in class was frequently expressed. (p.513)

Developing scientific attitudes. To examine the impacts of laboratory activities, Thompson (1976) analyzed the rating-responses of English sixth-form science teachers. The scientific attitudes that received a high rating from amongst the stated objectives were:

1. To encourage accurate observation and descriptions.
2. To promote a logical, reasoning method of thought.
3. To develop a critical attitude.

Other scientific attitudes that were considered important in Thompson's study but received a lower ranking included:

1. To develop self-reliance.
2. To develop an ability to communicate.
3. To develop an ability to cooperate.

Likewise, from a study conducted by Kempa and Dynan (1977), in the schools of Northern Ireland, scientific attitudes that were considered important by teachers and received a high rating were:

1. Cooperation in relation to safety procedures and other practices necessary for the efficient running of the laboratory.
2. Enthusiasm for the subject, especially its experimental basis.

Receiving a lower ranking, however still considered important, was the scientific attitude of: "persistence and resourcefulness in dealing with practical tasks."

Summary and Implications of the Literature Review

It is understood that even though this literature review may have been selective in its inclusion of earlier findings, it nevertheless portrays that research has not been exhaustive in its scope of determining the uniqueness of laboratory activity as a mode of science instruction.

The review however, shows that some studies have been conducted for laboratory activity in the following areas. (For purposes of the summary only the most recent references for the studies are cited as examples.)

1. Determining some of the impacts which are produced. (Nadeau 1984, Denny and Chennell 1986, Bryant and Marek 1987, Simpson and Oliver 1985, Blosser 1988, Lehman 1989))
2. Assessing teacher-student, student-student and student-program interactions. (Tobin 1986, Darlington 1986, Shymansky and Penick 1982, Beasley 1983)
3. Examining students' engagement rates on designated

laboratory tasks. (Tobin 1983, Tobin 1984, Okebukola 1985)

4. Indicating characteristics of different levels of laboratory inquiry. (Yager 1987, Nadeau 1984, Nagalski 1980)
5. Recognizing the three phases of laboratory activity and indicating some possible duties of teachers and students during these phases. (Nay 1986, Lunetta and Tamir 1981, Nadeau 1984)

From this literature review the following implications have significance for the present study:

1. Encounter with several research instruments, eventually used in the study. These include:
   (a) The Shymansky and Penick "Science Laboratory Interaction Categories" (SLIC) instrument used to systematically assess students interactions while performing hands-on laboratory activities.
   (b) Nadeau's system of analyzing student laboratory work for employment of the scientific process skills.
   (c) Fisher's "Attitude Survey for Junior High School Science" to provide a framework to obtain student responses on attitudes toward science in general and particularly on school science laboratory activity.
2. Focussing the researcher's attention on various aspects of laboratory activity, such as:

(a) Laboratory work should comprise a substantial portion of the science program.

(b) Process and content learning need to be considered together in planning a science program involving laboratory work.

(c) Laboratory investigations can range from low to high level inquiry depending on structuring and guidance provided by teachers or laboratory manuals.

(d) Three phases need to be considered in laboratory activity: pre-laboratory, laboratory work, post-laboratory. During these phases students and teachers have definite tasks depending upon the level of inquiry employed in investigations.

(e) Determining attitudes of teachers and students toward school science laboratory work.

(f) Student-student, student-teacher, and student experiment interaction during laboratory work.

(g) Extent of active involvement of laboratory group members during laboratory investigations.

3. Providing a base of comparison for findings that might accrue in the study.
4. Enabling the establishment of a theoretical base for patterns observed in collected data.

CHAPTER 3

DESIGN OF THE STUDY

In this chapter design issues for the main study are discussed. It includes the setting of the study, data gathering techniques, and data analysis procedures. A brief discussion of the pilot study and research methodology is also provided.

It will be recalled that the problem statement in Chapter One indicated that this study is an examination of what laboratory activity actually is at the junior high school level, and the learning outcomes that teachers and students attribute to it.

The Pilot Study

A pilot study was conducted to:

1. Provide an opportunity to develop and field test data gathering techniques, to assess their suitability for the main study, and to gain experience and expertise in using them.
2. Define more clearly aspects of the organization, interaction dynamics and impacts of laboratory activities to be examined further in the main study.
3. Allow the researcher to delimit the problem more meaningfully on the basis of the pilot data to laboratory activities per se rather than a comparison with other instructional methods.

The pilot study was conducted in three junior high schools in a large Alberta urban center. One grade nine science class from each school was observed for a period of one week. Grade nine classes were used since they are more readily accessible for observations, in that the Alberta science program at this grade level lends itself easily to laboratory work. During the observation sessions each of these classes was able to complete one or two laboratory investigations. The factors of school size and location as possible influences on laboratory activities were considered by selecting two elementary-junior high schools and one larger junior high school, each from a different section of the urban center.

In one of the elementary-junior high schools and the larger junior high school data were gathered by means of the following methods:

1. Making field notes, and tape recording conversations of teachers and students during all three phases of laboratory activities.
2. Capturing in field notes casual conversations of the researcher with several students and their teacher, in an attempt to determine what was happening as laboratory investigations were performed.
3. Tape recording interviews with the teacher and researcher selected students to obtain their views of, and attitudes toward laboratory activity, both in general and on specific experiments observed.

views of laboratory work in a written paragraph.

5. Photocopying and examining researcher selected students' notes or laboratory reports. These documents were indicators of how the scientific process skills are being used during laboratory activity.
6. Video taping actions of students and their teacher while the laboratory phase on one investigation was performed.

With experiences obtained from the pilot study in these two schools, modifications were made to data collecting procedures. Feasibility of these changes was examined in a second phase of the pilot study conducted in one class of an elementary - junior high school. The modifications made to the data collecting procedures, as a result of the pilot study, are as follows:

1. Writing of field notes for student behaviors and tape recording teacher and student conversations was restricted to pre- and post-laboratory phases of laboratory work. Taping student conversations during the laboratory phase was proven difficult due to background noise.
2. Student interactions and behaviors during the laboratory phase warranted closer scrutiny and a decision was made to use the Science Laboratory Interaction Categories checklist (SLIC), developed by Shymansky and Penick et al. (1979). This

conversations with students and the video taping of students performing laboratory activities. The latter two techniques proved to be too labor intensive in terms of the results that were yielded. The video taping also was difficult logistically. The SLIC checklist was used in observing three selected students in the third pilot school.

3. To provide a broader base of information all students within the class were requested to fill in a science opinionnaire containing 29 questions, which required responses from strongly agree to strongly disagree, and one open-ended question. This replaced the written paragraph in which students were asked to express their views of laboratory activity. It was found that many of these paragraphs lacked the degree of detail which was expected. A modified version of Fisher's Science Opinionnaire (1973) was used instead (See Appendix C). The reliability of this instrument as used in the pilot study was calculated by using student scores on odd and even numbered opinionnaire statements and found to be 0.84. Further description of the reliability of this instrument is provided later in its description as an instrument for the main study.

use of the scientific process skills. A description of how the three students were selected is outlined in the data collection techniques of the main study.

5. Interviews were conducted with three selected students within a class and their teacher. Data from interviews provided the participant's general view of laboratory work.

After the second pilot study no further modifications were made to the instruments as designated for use in the main study. However, from the results obtained by interviewing the selected students and their teacher it was decided to repeat the interviewing process more then once, whenever possible, in order to obtain a larger data base. It was also decided that by repeating the interviewing process more than once allowance would be made for additional probing, and for obtaining interviewee views of specific laboratory investigations.

The Main Study

Setting For The Study

One science class from each of three junior high schools, in a large Alberta urban school district, served as locations for the main study. In particular, observations were centered upon science laboratory activities in order to examine the three dimensions of organization, interaction, dynamics, and impacts. Observations of laboratory activities were made at the in a different school.

The time period allocated to observation at each school was three weeks. However, this time was divided into two separate blocks to possibly give the researcher an opportunity to observe student investigations in different units of the courses. This allowed the researcher to determine impacts, interaction dynamics, and organization, of laboratory activity as different topics were being studied. An attempt was made to include schools from various parts of the urban center: schools of different sizes, schools of different ages and schools located in different socioeconomic areas. This was done to take into consideration any influences on laboratory activities due to variation in availability of facilities and equipment.

With the researcher attempting to develop a picture of the dimensions encompassed by junior high science laboratory activities, it was necessary to avoid limiting the researcher's view to one particular location. By making observations in a number of schools and at all three grade levels it was possible to construct a more inclusive view of junior high science laboratory work.

Visiting of three different sites was manageable within the suggested time frame and also provided the scope of observations desired. After conducting three separate one week pilot studies, it seemed that a time period of three weeks of intensive observation within a class was laboratory activities. During the three weeks of observation assigned to each class, students could perform two or three laboratory investigations.

Data Collection Techniques

The pilot study indicated the feasibility of obtaining data from eight sources for the main study: researcher's field notes, photocopies of observed laboratory investigations, students' laboratory reports, science opinionnaire, teacher interviews, student interviews, tape recording of pre- and post-laboratory discussion and the Science Laboratory Interaction Categories (SLIC) checklist. Each of these data gathering techniques will now be discussed in detail.

Researcher field notes. Field notes were essentially composed of two parts - description and reflection. The descriptive aspect attempted to assist in setting out details of a laboratory activity. It must be understood, however, that it is impossible to capture an absolutely complete picture of any particular laboratory situation with field notes. Therefore, tape recordings were made of pre- and post-laboratory discussions. The tape recordings alleviated the need for recording all discussions in the field notes. However, this meant that the researcher still had to strive to record selected observations and conversations with as much detail and accuracy as possible. Whenever making a record of what to quote the conversation rather than simply summarizing it. By quoting terms, words, and phrases unique to the laboratory setting a more complete picture could be captured. Sometimes within the descriptive part of field notes drawings or sketches became useful. This was especially applicable in establishing the physical appearance of laboratory settings being observed.

With the researcher doing both the collection and analysis it became necessary to have a record of observer's feelings and assumptions - the subjective perspective of a researcher's observations. This personal accounting was included in reflective portions of the field notes. The subjective perspective allowed the researcher to express any problems encountered, make necessary corrections of misunderstandings, outline plans and procedures for further observations, and correct possible prejudices in recording observed situations. From reflective parts of field notes the researcher was in a better position for making assessments of the need for additional focussed observations as required. It also gave the researcher an opportunity to speculate, in a guided manner, about possible emerging relationships between individual elements of data. Thus, reflections in field notes were initial steps in establishing emerging patterns and themes of the interaction dynamics, organization, and impacts of laboratory activities.

Photocopying of investigations observed and students' laboratory reports. A copy of each of the investigations observed in this study was obtained for analysis purposes. In grade seven the investigations observed were from a reference book entitled, "Life Science - A Problem Solving Approach" (Carter et al., 1977), and the Curriculum Resources Information Bank (C.R.I.B.) (Edmonton Public School Board, 1974). The three investigations observed dealt with the photosynthetic process in green plants, and the internal structure of a leaf.

At the grade eight and nine level the investigations observed were taken, or adapted, from C.R.I.B. (Edmonton Public School Board, 1974). The grade eight investigations, cross referenced from C.R.I.B, pertained to determining the relative density of minerals, and identifying minerals. The grade nine investigations were concerned with identifying elements by flame tests, distinguishing between a mixture and a compound, and identifying the components of a mixture. (For further details see Appendix H).

As students work on their laboratory investigations it is general practice to have them fill in the required information within structured laboratory handouts, or to have them prepare their own laboratory reports, including those for open ended investigations. A request was made of the three selected students to have them provide the photocopied. These were collected once only for each particular laboratory report preparation format, even though the format may have been used several times again in the investigations observed over the three grade levels (e.g. collected once for a structured format, variations of semistructured formats, and an unstructured format). Usually, each of the documents for a given class were from a different laboratory group (e.g. the selected students being in different lab groups). With these documents indicating both the efforts of laboratory groups and individual students, they may contain important clues to the interaction dynamics, organization and impacts of laboratory activities.

Administering student science opinionnaire. The modified version of Fisher's opinionnaire (Appendix C) was included to obtain a broader attitude response to laboratory activities, in that all students present in a class completed it. Class time was obtained to administer this opinionnaire so as to have a better return of student replies, and to enable students to give more serious thought to the questions. Fisher initially developed his opinionnaire to obtain grade seven and eight students' attitudes toward science, and in particular attitudes toward laboratory experiments. To expand on the opinionnaire [illegible] and to have them cover areas of laboratory activities not included [illegible] questions the open-ended question was altered to make it specific to laboratory work.

The reliability of Fisher's initial instrument was determined by test-retest and split-half method using a rather small number of students. However, the reliabilities were reasonably high. For forty-three scores it was 0.793 and for thirty-nine scores 0.833. From a second phase of the current pilot study, student scores on odd and even numbered items were determined for the modified version of Fisher's opinionnaire, which included the 10 statements added by the researcher (See Table 1). In order to obtain the coefficient of equivalence for the full test the following formula was used.

$$rtt = 2\left(1 - \frac{Sa^2 + Sb^2}{St^2}\right)$$

Where; Sa and Sb are the standard deviations of the half tests, St is the standard deviation of the full test, and rtt is the reliability of the total test. From the scores obtained in the second pilot phase of the present study, which consisted of 25 student responses, the reliability was calculated as 0.84. Student scores on the modified opinionnaire were calculated on the basis of the five answer choices ranging from strongly agree to strongly disagree being weighted 5, 4, 3, 2 and 1. A weighting of 5 was assigned to the choice which the researcher considered

TABLE 1

Student Scores on Split Halves - Odd Numbered and Even Numbered Statements of Opinionnaire (Pilot Study)

Student Number	Student Score Odd Numbered Items	Student Score Even Numbered Items	Student Score on Total Test
1	52	45	97
2	44	45	89
3	52	51	103
4	57	52	109
5	51	50	101
6	59	51	110
7	53	47	100
8	51	48	99
9	42	46	88
10	60	55	115
11	53	56	109
12	52	44	96
13	62	65	127
14	54	59	113
15	54	47	101
16	31	36	67
17	56	57	113
18	51	48	99
19	61	50	111
20	50	51	101
21	51	50	101
22	56	54	110
23	56	62	118
24	57	60	117
25	59	53	112

phase of the pilot study, are examined with respect to the 10 questions added to Fisher's Opinionnaire by the researcher, it is found that generally there is high to medium consistency within responses given to each statement. This is reflected in the percent responses given in Table 2. Although in questions 25, 27, and 28 the largest percent response is less than 50%; the questions still tend to draw the student responses toward one direction on the continuum from strongly agree to strongly disagree. This also helps to establish reliability for the questions added to the opinionnaire.

Interviewing teachers and students. Three students from each class were selected for interviewing on the basis of scores obtained on a modified version of Fisher's science opinionnaire given to all students in a class. The students who obtained the low, medium, and high opinionnaire scores were selected. Interviewing students with these scores provided information from those tending to have a negative, neutral and positive attitude toward laboratory activities. These students, as well as their teacher, were interviewed on two or three occasions, if possible. A format of semi-structured interviews was used to allow for opportunities in focussing on specific topics. At the same time this gave the interviewer freedom to probe interviewee responses in depth to obtain more particulars

TABLE 2

Student Percent Responses For Questions 21-29 of Modified Fisher's Opinionnaire (Pilot Study)

Question Number	Percent of Students Responding With Agreement	Undecided	Disagreement
21	76	16	8
22	52	24	24
23	44	24	32
24	76	12	12
25	72	12	16
26	76	20	4
27	24	36	40
28	48	28	24
29	4	4	92

Appendix L for interview questions).

Most questions for interviews were designed to obtain explanatory or descriptive responses. Some of the questions asked were general, others related to specific laboratory activities performed by students, and some related to previously made interviewee statements. The latter type of questions allowed interviews to become cumulative, building upon each other, to obtain a more complete picture of participants' perspectives of laboratory activities. Throughout the interviews it was important to remember that the interviewer was attempting to acquire interviewee's point-of-view and not evaluating or changing their specific views. This meant that the interviewer needed to be an attentive listener, non-emotional, and inquisitive without being challenging or threatening to the interviewees.

Tape recording of pre- and post-laboratory discussions. Pre-laboratory and post-laboratory class discussions were captured by means of a tape recorder. These taped discussions were transcribed into a format which clearly identified the nature of the discussion, place, and date. Transcripts facilitated coding of the collected data and making of additional observer comments.

Pre-laboratory discussions, according to the literature, usually tend to be dominated by teacher talk, [illegible]ining procedures, identif

Post-laboratory discussions on the other hand can involve a considerable amount of student-teacher interaction, depending upon the teaching style of the teacher.

A small tape recorder was used and placed on a desk at the back of the classroom. Students soon appeared to ignore its presence. That is, student-student and student-teacher conversations during pre- and post-laboratory discussions seemed to occur as would be expected. These class discussions provided valuable insights into the organization, interaction dynamics and impacts of laboratory work.

Science laboratory interaction categories (SLIC) checklist. To observe interactions of three selected students during laboratory work phases of laboratory activities the student portion of SLIC was used. This checklist was prepared by Shymansky, Penick et al. (1979) and has been used extensively to assess interactions of students and instructors during college science laboratory activities. In testing this instrument Shymansky and Penick indicated that 82 half hour observations were made of lab instructors and 331 ten minute observations of students engaged in college laboratory activities. It was concluded that once familiarity of the behavior categories is achieved, detailed and reliable information is readily obtained by using this instrument. Okebukola (1985) found that a 20-man observer team, after receiving training, attained an 89% level of agreement in using SLIC to observe student behavior during laboratory work.

In the current study an instrument was needed to focus upon interactions occurring during the laboratory work phase, and student portion of SLIC met this requirement. However, the teacher portion of SLIC appeared to include interactions which could occur during the pre- and post-laboratory phases, as well as the laboratory work phase. Since verbal interactions of teachers and students during pre- and post-laboratory discussions had been captured by tape, and they also composed a substantial portion of the teacher segment of the SLIC checklist; it was decided instead to capture the non-verbal interactions of teachers during the three phases of laboratory activity in the researcher field notes.

The student SLIC checklist used in this study (See Appendix D) includes three dimensions of interactions:

(a) specific behaviors being exhibited.

(b) to whom behavior is being directed.

(c) sex of individual to whom interaction is directed.

In the present study the intent is to determine what student behaviors are occurring. Consequently only the first interaction dimension of SLIC was observed (See Appendix D). Each student was observed with the SLIC checklist for approximately 10 seconds and then attention was shifted to the next student. When all three students had been observed, the first student was observed again. This sequence continued for 10 to 15 minutes, or until the laboratory work phase was completed. One SLIC checklist was used for each student and as a specific behavior was observed, or appeared to be occurring, a check mark was placed in the appropriate interaction category. When more than one behavior was observed the most predominant one was checked off. Each student was observed in this manner on two or three separate occasions.

Procedure for Treatment of Data

In this study analysis was considered an ongoing process and began as data was collected (See Figure 1). Analyzing the data in this manner guided to some extent the development of additional interview questions and the focussing of observations. A description of analysis procedures used for each data gathering technique follows.

Researcher field notes. After writing field notes for an observation session, the notes were read and coded in margins of the page with key words or phrases to indicate what was being said or experienced. An examination of coded headings provided a means of easily noting regularities or patterns which appeared to be developing. These emerging patterns served to focus further observations and guided development of questions for student and teacher interviews. Upon completing data collection, coded field notes were combed for recurring themes within each of the three dimensions of laboratory activity - organization, interaction dynamics, and impacts. Themes which emerged from researcher field notes were

Data Collection

- administering of science opinionnaire to students
- writing of field notes describing school setting and laboratory activity
- taping of pre-laboratory discussion
- transcribing of pre-laboratory discussion

↓

Data Analysis

- tabulating student opinionnaire responses
- selecting the students providing the most favorable, medium, and least favorable opinionnaire responses
- calculating the mean response and percentage of students choosing response categories for each opinionnaire item
- tabulating opinionnaire item responses for the three selected students
- developing teacher and student interview questions so as to probe into opinionnaire responses

↓

Data Collection

- interviewing of selected students and their teachers
- observing selected students with the SLIC checklist during laboratory investigations
- writing additional field notes
- transcribing taped interviews

↓

Data Analysis

- examining of SLIC checklist results and researcher field notes to develop further interview questions
- searching for patterns in opinionnaire responses, interviews, and SLIC checklist

↓

Data Collection

- taping of post-laboratory discussions
- further interviewing of selected students and their teachers
- transcribing of post-laboratory discussions
- obtaining photocopies of student laboratory notes or laboratory reports for observed investigations
- writing of additional field notes

↓

Illustration of Data Analysis Procedures

Figure 1

FIGURE 1 (Cont'd)

Data Analysis

- examining of student notes or laboratory reports for student use of scientific process skills and level of inquiry
- determining and tabulating means and standard deviations for each opinionnaire item
- tabulating opinionnaire responses for all selected students at each grade level
- searching data from each source for patterns
- finding relationships between patterns from different data sources
- establishing themes for findings in collected data

triangulated with findings in data collected with other techniques. The researcher field notes are summarized in Appendix G.

Laboratory investigations observed. Copies of the investigations observed were obtained from the three teachers (See Appendix H). These investigations in conjunction with researcher field notes, student lab reports, and taped pre- and post-laboratory discussions were analyzed for the incorporated scientific process skills and their level of inquiry. The analysis was done on the basis of Nadeau's instrument shown in Appendix B. In each investigation the process skills were monitored for the pre-laboratory, laboratory, and post-laboratory phases of laboratory activity. Three categories were assigned to show how the process skills were used during investigations. These included: initiated by student, guidance provided by teacher, and guidance provided by laboratory manual. A column was also provided for researcher comments. For each investigation, the percent of the process skills that have to be initiated by the student was calculated. This analyzed data for the investigations observed is shown in Appendix I.

It is possible to use Nay's Chart on Characterization of An Inquiry Lesson (1970), shown in Appendix E, to establish a level of inquiry for each investigation. However using the percentage of process skills initiated by students, as determined with Nadeau's instrument, is perhaps a more rigorous method. This method allows for the delineation of a larger number of levels of inquiry, and therefore is able to show a clearer distinction between investigations being performed by students. To assess the difference in level of inquiry, for the investigations being used, the following scale was arbitrarily established:

% of Process Skills Initiated	Level of Inquiry
0 - 20 %	low level of inquiry
21 - 40 %	fair level of inquiry
41 - 60 %	moderate level of inquiry
61 - 80 %	high level of inquiry
81 - 100 %	very high level of inquiry

Student laboratory reports. In most instances, the report consisted of filling in blanks in a handout provided by the teacher. In these cases the responses of all three students in a given school were collated into the space provided in the handout to facilitate comparison of student answers (See Appendix J). Such reports were not analyzed further for scientific process skills on the basis of Nadeau's scheme since this was already done for the laboratory investigations (See Appendix H). In cases where no class handout was used (e.g. the open-ended investigation at Aston School) the laboratory reports are given verbatim in Appendix J. These reports were analyzed on the basis of Nadeau's scheme and are also included in Appendix I. The summaries and analyses of these reports are used in the next chapter to identify patterns and generalizations regarding such aspects as: use of scientific process skills, level of inquiry, and learning of science concepts.

Student science opinionnaire data. After students had completed the opinionnaire it was dated, and assigned a code for the school name to maintain anonymity. For purposes of analysis the five responses for each opinionnaire statement, which ranged from strongly agree to strong disagree, were given numerical weightings of 1 to 5. For purposes of this study, a weighting number of 5 was assigned to the opinionnaire statement response deemed by the researcher to be most favorable to a science laboratory activity program. A weighting number of 1 was assigned to the opinionnaire statement response considered by the researcher to be least favorable to a laboratory activity program. Hence the maximum score obtainable on the opinionnaire was 145. These weightings were then used in all analyses of opinionnaire responses. To facilitate analysis opinionnaire statements were assigned to the categories of: nature of laboratory activity, and impacts of laboratory activity.

As students at each school completed the opinionnaire, weighting numbers were placed in margins opposite student statement choices. The weighting numbers of all opinionnaire statements were then transferred to a chart constructed for each school, and from these the mean and standard deviation were calculated for each statement. A percent response of the five available choices for each statement was also determined. An Apple IIe computer statistical package was employed in determining the standard deviations and means of student opinionnaire responses.

From opinionnaire responses those students providing the most favorable (highest score), moderately favorable (closest to the middle score), and least favorable (lowest score) at each school, were selected as the three students who were interviewed and also observed using the SLIC instrument. For data analysis the opinionnaire responses were used to make comparisons with interview statements and observed interactions during laboratory activity. Accordingly, research findings cited through one means of data collection were triangulated with those from other data sources.

Student responses to the open-ended opinionnaire statement (I think science laboratory work is) were edited and then summarized into a chart for each school setting. These statements were examined for patterns within each of the three dimensions of laboratory activity: organization, interaction dynamics, and impacts. Established patterns were summarized for each laboratory dimension in a chart showing student responses for the three schools observed. Any themes indicated in the open-ended opinionnaire question were compared with those portrayed during interviews, student laboratory activity interactions, and the structured opinionnaire questions.

Recorded interviews. All taped interviews with nine selected students and three teachers were transcribed by the researcher. As each transcription was re-read notations were made in margins of the pages to indicate main conversation topics. Then all of the interviews were collated and summarized (See Appendix M for interviews of teachers and Appendix N for interviews of students). From the margin notations patterns were established within and between interview discussions. With interviews being guided by semistructured interview questions, which allowed for spontaneity of questioning as determined by responses, individual interviews possessed differing degrees of detail. As indicated previously, the patterns established during interviews were compared to those obtained with other data collection techniques (e.g. opinionnaire and field notes).

Recorded pre- and post-laboratory discussions. Upon transcribing a taped pre- or post-laboratory class discussion, a search was made for recurring patterns. Notations were made in the margins of the transcribed discussions to indicate patterns for the three dimensions of laboratory activity. From patterns noted in transcriptions themes were established. Whenever these themes are cited in the study, they are supported with direct quotations from the pre- or post-laboratory discussions to capture the participants' own words. Themes indicated in pre- and post-laboratory discussions were also searched for in data collected by means of other methods. A summary of the recorded pre- and post-laboratory discussions is given in Appendix O.

Science laboratory interaction categories (SLIC) data. Three students from each school, as selected from responses on the science opinionnaire, were observed during two or three investigations with the modified Shymansky, Penick, et al (1979) SLIC checklist (Appendix D). This checklist provided 10 categories in which student interactions could be observed. Check marks were placed opposite the observed interactions for each student, as they participated in the performing of a laboratory investigation. These students were not aware that they had been selected for observation purposes. This was done so as to avoid observational results being laden with students interactions that were fabricated as a display, and therefore not authentic. For data analysis purposes the check marks in each interaction category were tallied over all the investigations observed with a specific student. These totals for each interaction category were then translated into a percentage of observed laboratory time a student spent in performing a particular interaction. The findings from the SLIC checklist were used in conjunction with the findings from interviews, and the science opinionnaire to compare patterns and to establish predominant themes.

Research Methodology

Within the present study a qualitative research mode is used to determine how junior high school students and their teachers view the operations and impacts of school science laboratory activities. In this section a brief review is provided of qualitative data collection and analysis techniques, the means of establishing reliability and validity, and ways of reducing researcher bias. Qualitative research techniques, particularly interviewing and participant observation, have been respected and used regularly in sociology and anthropology research for many years. Wilson (1977) put it into perspective by stating that:

> These methods have been found to be useful for gathering certain important kinds of data, in fact, some researchers claim that these anthropological techniques may gather information about human behavior that it is impossible to obtain by the more quantitative methods. (p. 246)

In a qualitative research approach multimodal methods for data collection can be used. The methods used are determined by the kinds of data sought. Within this approach the researcher is present at the situation being studied, and is at least a mental participant in the events that are occurring, and therefore can be considered as a low level participant observer. West (1977) extends this to other data collecting methods by indicating that "most practicing participant observers have developed a style which combines observation and participatory insights with formal and informal interviews with respondents and informants, questionnaire data, and official records" (p. 62-63).

Data analysis in qualitative research occurs in conjunction with data collection. That is, analysis of data collected for each field work session is used as a guide for the next session of data collection. According to Bogden and Biklen (1982) and Spradley (1980) analysis involves organizing and working with the data collected in a "search for patterns".

Means of Establishing Reliability and Validity

Reliability for the qualitative researcher relates to the accuracy of collected data as pertinent to a specific situation. Lecompte and Goetz (1982) state "that a researcher's failure to specify precisely what was done may create serious problems of reliability" (p. 36). Consequently, to facilitate reliability certain techniques are useful. This requires giving attention to precisely describing the following:

1. Roles researcher engages in while on site (e.g. participant observer, interviewer).
2. How informants are identified and the number involved.
3. Physical and social characteristics of the setting visited.
4. Data collection and analysis strategies used.
5. Cited researcher observations and informants

verbatim comments and conversations.

Validity is concerned with the adequacy of findings to represent a situation, e.g. sufficiency of evidence. This involves assessing whether researcher's observations authentically represent reality of the situations studied (internal validity). To establish validity the following are helpful:

1. Encouraging of positive researcher-participant relationships (e.g. trust, honesty, respect).
2. Asking questions of informants during interviews in several different ways.
3. Interviewer avoiding expressions of any kind which indicate disapproval of an informant's comments and consequently influencing statements made.
4. Checking results of one observation or interview with the results from another observation or interview for agreement (multiplicative corroboration).
5. Searching more than one source of information for agreement on a particular conclusion reached. Qualitative researchers refer to this as triangulation.
6. Citing other related studies where findings are in agreement with those currently obtained.
7. Checking interpretations of interview transcripts with interviewees.

Observer Bias

Observer bias in qualitative research can be reduced by procedures such as:

1. Reviewing of field observations with participants.
2. Using instruments where the researcher simply codes the observations. With these kinds of instruments the observational framework is already provided, and therefore avoids researcher bias. (e.g. SLIC checklist)
3. Checking observational evidence with information obtained by other means, e.g. interviews. Consequently, if bias is creeping into the observational data, the observer is more likely to be alerted to its existence.

Observer bias however cannot be eliminated, but only minimized by procedures such as the above. The interests and prior experiences of the researcher have some bearing on data collection and analysis. Qualitative researchers attempt to acknowledge and then try to take into account their own biases during the data collection and analysis. The following is a description of what the researcher brought to the present study.

During the past twenty years I have spent fifteen years in the junior high school classroom teaching science, three years as a full time graduate student, and two years teaching senior high school chemistry. My viewing of laboratory activities as a natural aspect of studying science can be rationalized in two ways:

1. Through having practical experience with laboratory activities in junior and senior high school science, and directly observing its effects.
2. Having spent several years studying science as an undergraduate student in the faculties of science and education.

I consider laboratory activities as allowing students to be active participants in the learning process rather than receivers of information or passive participants. With active involvement science becomes more meaningful to students. This hopefully results in a renewed enthusiasm and interest in science for many students who normally find science dull or boring. Further, laboratory activities are considered as allowing students to better understand the nature of science. By using scientific processes during laboratory work students have a chance to experience, to some degree, aspects of how scientists go about doing science.

Although I see laboratory activities as fitting naturally into the teaching of science, they are by no means considered as the sole component. Not all students enjoy laboratory work, find it interesting or learn adequately from it. Consequently, the use of many different teaching techniques is considered desirable, not only for meeting the requirements of various styles of learning, but also to provide needed variety. Overworking of a teaching method soon results in monotony for students. Laboratory work is not an exception.

My interest in the present study stems from a desire to obtain an in-depth understanding of how students and fellow colleagues view and perform laboratory activities. Teachers seldom get to see other teachers in actions, or have the time to find out what students and teachers really think about laboratory work in the teaching of science.

Ethical Issues

Administrators of participating schools were contacted in person to obtain approval of the research being conducted in their schools. Thereafter, participating teachers were contacted in person to obtain their approval to be observed and tape recorded in the classroom/laboratory, and to be interviewed by the researcher.

Student permission to participate in the study was obtained from parents or guardians (See Appendix Q for permission letter). The permission letter was provided during both the pilot and main study. Students were also given the option of withdrawing from the study at their own discretion.

In order to protect participants all tape recordings made are to be destroyed when the study is completed. Participating schools, teachers, and students are given fictitious names to maintain anonymity.

Permission letters, requesting approval, were sent to the publishing company or persons holding the copyright for the laboratory investigations included in Appendix H (See Appendix Q for copies of these letters).

Summary

Chapter Three provides a description for setting, data gathering techniques, and analysis procedures used during this study. It also outlines the pilot study which was conducted, and briefly reviews qualitative research methodology.

The pilot study was conducted in two separate phases. In the first phase two grade nine classes, each from a different urban junior high school, were observed for a time interval of one week each. While visiting these schools the researcher field tested data gathering techniques, attempted to define with more clarity the dimensions of laboratory activity, and delimited the problem to be studied. After phase one substantial modifications were made to the data gathering techniques. Consequently, phase two was conducted, at one urban school for one week, to field test these modifications.

Setting for the main study is within three urban Alberta junior high school classrooms. At each school one class was observed, either grade 7, 8, or 9. During a three week visit at each school the researcher observed the science laboratory work for a specific class. On two or three occasions three selected students and their teacher were interviewed to glean from them their views of laboratory activity. To make the study more inclusive of junior high school laboratory activities, the three week observation period at each school was divided into two separate blocks. This allowed the researcher to observe laboratory activities for different course content areas at a particular grade level.

Several observational and interview data gathering techniques are cited and elaborated upon. Researcher field notes are shown as having two components, recorded observations and observer comments. Interviews with students and teachers are described as being captured by tape recorder and thereafter transcribed. Pre- and post-laboratory class discussions are dealt with in a similar fashion. Selected student laboratory reports or notes serve as documents which are analyzed to illustrate student use of scientific process skills during laboratory activities. The following two formal instruments are also cited for gathering of data:

1. A Modified Version of Fisher's Science Opinionnaire.

This opinionnaire was administered to all students within a class to get a broader attitude response to the three dimensions of laboratory activity.

2. Shymansky, Penick et al., Science Laboratory Interaction Categories (SLIC) checklist.

This checklist was used to observe the interactions of three selected students in a class while engaged in the laboratory work phase of their science investigations.

Data analysis is portrayed both as occurring concurrently with data collection and also as a final event in itself. Student opinionnaire responses and researcher field notes were scrutinized immediately for regularities or emerging patterns. These findings were then used in focussing interviews and making further observations. Likewise, transcribed interviews and pre- and post-laboratory class discussions were examined for emerging patterns, and from these patterns themes were established. The Shymansky, Penick et al. SLIC checklist was translated into percentage of observed laboratory time a student spent in performing particular interactions. These interaction percentages for selected students were then searched for patterns. Student notes or laboratory reports were searched with Nadeau's (1984) format to determine the degree of student participation in using the scientific process skills. From an arbitrarily established scale and the percentage of process skills initiated by students, as indicated by Nadeau's instrument, the level of inquiry for student investigations was established. Patterns emerging from each of the data collection techniques were compared in order to determine the primary themes as indicated in the study.

CHAPTER 4

RESULTS OF THE STUDY

In this chapter the findings from three science laboratory classrooms, each in a different junior high school, are presented and described. Information is provided for a grade seven class at Arfvedson Junior High, a grade eight class at Chadwick Junior High and a grade nine class at Aston Junior High. Although the situations described are real, names of schools and persons are fictitious in order to maintain confidentiality and anonymity.

The findings presented in this chapter are based on eight sources of data: student responses to a science opinionnaire, teacher interviews, student interviews, researcher's field notes, taped pre- and post-laboratory class discussions, observations made with the Student Science Laboratory Interaction Categories (SLIC) instrument, printed forms of the laboratory investigations observed, and students' laboratory reports. There is too much "raw " data to include in this thesis, hence only processed data is usually presented, primarily in the appendices. This information is retrieved as needed in the presentation of the results of the study, summarizations, and explanations of the data. In Chapter 5, the data obtained by means of these different techniques is combined to give a holistic in-depth interpretation of laboratory activities.

Research Setting

The research setting will be described in terms of the individual schools and classes observed. Information with regard to the teachers will be given in generalities rather than specifics to maintain anonymity. This description is provided to facilitate visualization of the class settings which were studied.

Arfvedson Junior High School (Grade 7)

Arfvedson is a large junior high school with several classes of science at each grade level. Consequently, several teachers were required in teaching of science. The grade seven class being considered took science in a large science laboratory type classroom with ten available laboratory island stations, eight larger and two smaller ones. Each of the eight larger island stations were equipped with two sinks, two gas outlets, and two electrical plug-ins and could easily accommodate six students in doing their laboratory investigations. The two smaller stations had only one sink, one gas outlet, and one electrical plug-in, and three students could work comfortably at these stations. The larger island stations were surrounded by four trapezoidal tables which could be moved away from the laboratory stations if necessary, or could be used as an extension of the stations.

The school was equipped with sufficient supplies and equipment to have students involved in laboratory activities. The laboratory/classroom was located adjacent to the preparation room in which equipment and materials were stored and therefore readily accessible to the teachers. Students worked at the laboratory tables in groups of 2 or 3, which they had picked for themselves usually on the basis of sitting in a certain location within the room. Laboratory work was thought of as being an important component in grade seven science, and according to the teacher, Mr. Scheele, comprised about half of the course he provided. A part-time laboratory aide provided some assistance to teachers in preparing for laboratory activities.

Mr. Scheele had over 15 years experience in teaching science at the junior high school level, was the coordinator of the science department in the school, and had some other general administrative experiences in the school system in which he worked. While this study was being conducted in Arfvedson Junior High School, Mr. Scheele had an intern teacher working with him. Although the grade 7 class observed was conducted by the intern teacher, Mr. Scheele was either present or close at hand, and particularly when students performed laboratory investigations he was present to assist them.

Students at Arfvedson Junior High took science three times a week, with each class period being of a 60 minute duration. Students therefore seemed to have sufficient time to complete the laboratory activities that were assigned. Generally students at Arfvedson came from middle income families.

The grade 7 class observed was composed of 22 students, two of whom were absent during the period in which the science opinionnaire was administered. Of the students who responded to the opinionnaire, 15 were boys and 5 were girls. Three students (Karl, Jacob, and Olaf) were selected as having the most, intermediate and least favorable attitude, respectively, toward science and laboratory work as indicated by class responses to the science opinionnaire. Their scores were 117, 99 and 81 respectively, out of a total possible score of 145. These three selected students from Arfvedson were interviewed, observed with the SLIC grid while performing the hands-on portion of laboratory activities, and provided copies of their laboratory notes and/or reports to the researcher.

Chadwick Junior High School (Grade 8)

Chadwick was a small elementary-junior high school where one teacher taught essentially all of the junior high science classes. Laboratory work was also considered important in the teaching of science at Chadwick Junior High. The teacher, Mrs. Dalton, indicated that laboratory activities comprised about 50% of her grade eight science course. Mrs. Dalton was engaged in science in-services and other curricular activities outside of her school. Mrs. Dalton had less than 10 years of teaching experience.

The grade eight students observed at Chadwick had science in a large laboratory classroom. This room was large enough to have students separated from the laboratory tables when not engaged in hands-on activities. In addition there was enough space for a demonstration lab table at the front of the class. For regular class activities students were seated at trapezoidal tables and for hands-on laboratory activity they moved to the back of the room to work at three long laboratory benches. Each of these benches contained two sinks, one at each end, along with eight gas outlets, and several electrical plug-ins. Students could be stationed on both sides of the laboratory benches and had enough space to work very comfortably. Students did laboratory investigations in groups of two, with the occasional group consisting of three members. Although there were some laboratory groups consisting of both boys and girls most groups were either all boys or girls. Students were assigned to these groups by their teacher.

Laboratory equipment and materials were stored in a preparation room next to the classroom and therefore were readily available to the teacher. It seemed that a good supply of equipment and materials were available for student investigations. A part-time laboratory aide was available to provide some assistance to Mrs. Dalton in setting up for laboratory activities.

The grade eight students at Chadwick had science four times a week, with the class periods being of different lengths on different days. Students had science for 208 minutes each week with the class periods varying from 40 to 63 minutes. Students at Chadwick, in general, came from middle to high income families.

The grade 8 class observed at Chadwick Elementary-Junior High School consisted of 29 students. Three students were absent on the day the science opinionnaire was administered, and one student was not granted parental permission to participate in the study. Of the 25 students who responded to the opinionnaire 12 were girls and 13 were boys. From results of the science opinionnaire in this class three students were selected for interviewing, observing with SLIC grid during hands-on activities, and providing notes or reports for scrutinization. Marie, Alfred, and Irene, gave most, intermediate and least favorable responses respectively to the opinionnaire questions. They had scores of 119, 99 and 70 respectively, out of a total possible score of 145.

Aston Junior High School (Grade 9)

Aston was an elementary-junior high school with a medium-sized junior high school student population. Mr. Priestley taught all of the grade eight and nine science classes, while another teacher taught grade seven science. Laboratory work according to Mr. Priestley made up about 40% of his grade nine science course. Mr. Priestley had over 15 years experience in teaching science at the junior high school level. He was coordinator of the science department in his school, and had some administrative experience within the school system in which he worked. Mr. Priestley also was involved in curriculum activities outside of his school.

The grade 9 class observed at Aston Elementary-Junior High did laboratory investigations in a laboratory classroom which had 10 available stations. Of these stations, 5 were located on free standing laboratory tables at the back of the room, 3 were against a side wall, and 2 were on the demonstration table at the front of the class. Each of these stations had its own sink, gas outlet, and electrical plug-in. When not engaged in hands-on activities students sat at long tables in the middle of the classroom. Each laboratory group consisted of three or four members with students choosing their own partners usually on the basis of the seat location they had chosen in the classroom. Most groups consisted of all girls or all boys. Mr. Priestley did not have a laboratory aide. It appeared that Aston school had sufficient materials and equipment to involve students in laboratory investigations. These supplies were stored in a preparation room adjacent to Mr. Priestley's classroom.

The grade 9 students observed took science 4 times a week, with class periods being 45 minutes in length. Students at Aston Elementary-Junior High came from middle to low income families. The class observed consisted of 28 students, with 6 students absent on the day the science opinionnaire was administered. Of those students who responded to the opinionnaire 7 were girls and 15 were boys. From these class members Nicolas, Rachel, and Elaine were selected for interviewing, observing during laboratory activities, and providing their laboratory notes and/or reports for further study. These three students had scores of 117, 105 and 89 respectively, out of a total possible score of 145, on the opinionnaire (which is a measure of the students' attitude towards science and laboratory work).

Results Obtained

As was mentioned earlier there were eight sources of data in the main study. The results provided by each of these sources will be presented presently. In the next chapter the presentation and discussion of the results will be carried out relative to the three guiding questions of the research study: the organization of laboratory activities, the student interactions during laboratory activities, and the learning outcomes attributed to laboratory activities.

The Laboratory Investigations Observed

Copies of investigations observed at each of the grade levels are provided in Appendix H. Investigations performed at Arfvedson were generally taken from the Curriculum Resources Information Bank (C.R.I.B.) (Edmonton Public Schools, 1974) and prescribed reference books such as, Life Science: A Problem Solving Approach (Carter et al., 1977) These laboratory exercises usually had extensive structuring to guide students. An examination of the grade 7 investigations used reveals that students were provided with a problem statement, purpose, list of materials, procedure, and inference questions. However, as indicated by Mr. Scheele, more open-ended inquiry was also used at appropriate stages during the school year. While the researcher was at Arfvedson for a three week period of data collection, students worked on three investigations related to photosynthesis (See Appendix H).

The Curriculum Resources Information Bank (C.R.I.B.) served as a reference for the two laboratory investigations observed at Chadwick Junior High. However, some of the structuring or guidance imposed by laboratory notes was removed from Investigation One by having students prepare their own laboratory reports. Consequently, students were required to use more of the scientific processes on their own. This is illustrated to some extent by an inspection of Investigation One as used at Chadwick, in that it required students to write a paragraph expressing the inferences that can be made from the observations. Both investigations observed at Chadwick were concerned with using physical tests for mineral identification (See Appendix H).

In two of the investigations observed at Aston the Curriculum Resources Information Bank (C.R.I.B.) was used as a source. These investigations had extensive structuring, which included a problem statement, background information, list of needed materials, a design, charts for recording of observations, and inference questions. An open-ended investigation used as a culminating exercise to the unit was also observed. In this open-ended investigation, as shown in Investigation Three, (Appendix H) students were only provided with a problem statement and the needed materials. After designing and performing the experiment, students were required to write a laboratory report which included the problem statement, hypothesis, experimental design, observations, and a generalization or inference statement. Consequently, students were engaged in initiating a number of the scientific process skills. The three investigations observed during a three week stay at Aston, were concerned with distinguishing between elements, compounds and mixtures (See Appendix H).

Analysis for scientific process skills. Each investigation observed was analyzed for process skills using Nadeau's instrument (Appendix B). These analyses are given in Appendix I and summarized in Table 3. Laboratory manual initiated process skills were obtained from an analysis of the observed investigations, whereas teacher and student initiated process skills required analysis of the laboratory investigations in conjunction with researcher field notes (Appendix G), taped pre- and post-laboratory discussions (Appendix O), and student laboratory reports (Appendix J).

TABLE 3

Summary of Analysis of Investigations Observed

INVESTIGATON			Process Skills Provided by			Total Number of Skills	% of Skills Provided by Student	Estimated Level of Inquiry
Grade	Number	Title	Manual	Teacher	Student			
7	1	Food Produced by Green Plants	13	6	7	26	27	Fair
7	2	When do Leaves Contain Starch?	13	5	8	26	31	Fair
7	3	Internal Structure of Leaf	11	4	9	24	38	Fair
8	1	Relative Density	10	10	19	39	49	Moderate
8	2	Identification of Minerals	8	3	10	21	48	Moderate
9	1	Flame Tests	10	5	6	21	29	Fair
9	2	Distinguish between Mixture and Compound	10	5	10	25	40	Fair
9	3	Identify Components of Mixture	0	7	16	23	70	High

Note: Scale used to determine level of inquiry from percentage of process skills initiated by students.
0-20% low, 21-40% fair, 41-60% moderate, 61-80% high, 81-100% very high

For the grade seven investigations observed, Table 3 indicates approximately 50% of the process skills are initiated by the laboratory manual. Along with the moderate teacher involvement in process skill initiation (i.e. about 20%) the investigations result in only allowing for a fair level of student inquiry. That is, these investigations provide a relatively high level of structuring and guidance for students. It can be seen in Table 3 that the number of process skills provided by students in each of these investigations is essentially the same.

For the Grade 8 investigations the number of process skills initiated by students is higher than those initiated by the teacher or manual. As shown in Table 3, students initiated approximately 50% of the process skills in each of the grade 8 investigations observed, while the teacher and the laboratory manual combined to make up the other 50%. As a result the level of student inquiry is increased to moderate. The modified investigation format employed in the grade 8 investigations (e.g. students writing their own inferences) required a greater extent of student involvement. This is reflected in Table 3 by the larger percentage of skills provided by students compared to grade 7.

The open-ended investigation observed in grade 9 had a much higher percentage of process skills initiated by students than did the other two grade 9 investigations which followed the more structured format of C.R.I.B. (e.g. 70%, against 29% and 40%). It should be noted that the number of process skills provided by the teacher is only slightly greater in the open-ended investigation than in the other two investigations, and that no guidance is provided to students by the laboratory manual. This meant that students were required to initiate more of the scientific process skills for themselves.

Level of inquiry. From Table 3 it can be seen that the level of inquiry for the laboratory investigations observed varied from fair to high. The level of inquiry was estimated by the percentage of process skills provided by students on an arbitrarily established scale. The characteristics of fair, moderate, and high level inquiry was determined on the basis of the following table.

Percentage of Process Skills Initiated by Students	Level of Inquiry
0 - 20 %	low
21 - 40 %	fair
41 - 60 %	moderate
61 - 80 %	high
81 -100 %	very high

As indicated in Table 3, the inquiry level of most of the investigations (56%) was considered fair. In fair-level inquiry, structuring of laboratory activities and lab notes by the teacher is generally extensive while the degree of student independent learning, self direction and creativity is at a fairly low level. During fair-level inquiry, as exemplified by Investigation One grade 7 (Appendix H), students are supplied with a problem statement, provided with background information, and given directions and guidance for data collecting, processing of data, and data interpretation. Consequently, this type of investigation basically serves to illustrate a scientific concept. In grade seven fair-level inquiry is used frequently, perhaps due to students' lack of basic scientific knowledge and lack of experience with laboratory apparatus and techniques.

Both of the grade 8 investigations observed are illustrative of a moderate level of student inquiry. During these investigations students were provided with a problem statement (which they had to restate in their own words), background information, a list of materials, steps to be followed in performing the investigations, and charts for recording of data. Students were left with the responsibilities of providing a hypothesis, defining variables, listing precautions (some help given by teacher), writing of inference statements, answering provided interpretation questions and writing laboratory reports.

High-level inquiry, is illustrated by Investigation Three, grade 9 (Appendix H). Students were given a problem statement and asked to use previously learned laboratory techniques and scientific concepts to find a solution to the problem. This required students to design their own data collecting activities, means of processing data, and generalizations. This investigation could be classified as problem solving (See Characterization of an Inquiry Lesson, Appendix E). In high-level inquiry activities students also wrote laboratory reports.

According to Table 3, low-level inquiry and very high-level inquiry were not seen in the investigations observed. Very high-level inquiry would require students to develop their own problem statement in addition to the requirements of high-level inquiry, while in low-level inquiry all segments of the laboratory activity, except for the gathering of data, would be provided for the students.

Students' Laboratory Reports

The collated laboratory reports of three selected students in each grade are given in Appendix J.

It should be recalled, as mentioned in Chapter 3, that laboratory reports were collected in order to report preparation format. Four preparational formats of laboratory reports were collected:

1. Student answers to a pre-laboratory worksheet, and answers to provided inference questions.
2. Student answers to provided inference questions only.
3. Student laboratory reports which followed a teacher or manual specified structure (e.g. problem, background information, prediction, observations, and inferences).
4. Student open-ended laboratory investigation reports

which did not follow a teacher or manual specified structure.

The laboratory reports following a particular format, as prepared by 3 selected students, were compiled into one composite. This facilitates comparison of student responses in determining student effort and understanding. On each composite laboratory report for an investigation a legend is provided to indicate recognition of individual student responses. This was done for all investigations except the open-ended ones, which were retained as individual laboratory reports. Open-ended investigation laboratory reports were uniquely different from each other, and consequently compiling the three reports would probably destroy their uniqueness.

In the grade 7 investigations where students handed in answers to the provided inference questions, students responded to the questions with differing degrees of sophistication and understanding. This is illustrated in the grade 7 inference response statements for Investigation One (See Appendix J).

Question 8: If the white part of the onion contained sugar, how do you think it got there?

This question received the following responses:

Karl (high attitude student): Glucose got from the green to the white part of the onion by diffusion.

Jacob (intermediate attitude student): The glucose probably got there by diffusion.

Olaf (low attitude student): I think glucose travels throughout the whole plant during photosynthesis.

Karl responds with a definite answer, Jacob seems somewhat unsure of his answer by using the word "probably", and Olaf fails to provide an appropriate answer to the question. Olaf's lack of understanding of diffusion is further illustrated in question 9 where he is asked for evidence to show that glucose is able to pass through the cell membranes and move to different parts of the plant. He responds with "I found that glucose travels through the veins to various parts of the plant". It would seem that without addressing Olaf's misunderstanding during the post-laboratory discussion, Olaf would leave the laboratory activity with a misconception of how food is distributed through out the various parts of a green plant. In some cases answers to inference questions were missing perhaps indicating that the grade 7 student did not understand the question, or was unable to formulate an answer because of a lack of understanding. For example, in Investigation Two Olaf failed to provide answers to the inference questions, but nevertheless still handed in his incomplete report.

For the grade 8 laboratory reports individual student designed statements are formulated around a common structured framework (e.g. problem statement, hypothesis, variable identification, precautions, data and observations, inferences, and questions). The student statements showed differing degrees of understanding of the investigation. This is indicated, for instance, by the response students gave to the question "What is the meaning of relative density?" (Question 1, Investigation 1, Grade 8, Appendix J)

Marie (high attitude student): Relative density is the mass of an object when placed in water, the loss of weight from air to water will be density.

Alfred (intermediate attitude student): A comparison of the weight of a substance to the weight of an equal volume of water.

Irene (low attitude student): Relative density is how dense a mineral is compared to water.

Even though all students had been exposed to the pre-lab worksheet involving relative density calculations, and had also completed performing the relative density investigation, they had differing degrees of understanding as to what was meant by relative density. All sections of the report were completed by students. This report format also allowed for an element of scientific honesty. By students having the freedom to write their own inferences they could interpret honestly what their data indicated. For instance, for different samples of a given mineral the relative density was found not to be the same. Therefore, Irene inferred, that "relative density is not reliable in identifying, because each mineral sample differs even if it is the same kind of mineral."

The open-ended investigation in grade 9 gave students the responsibility of developing an experimental design to solve the problem as well as deciding how to report what they had found. Nicolas (high score student on opinionnaire) prepared his report by writing the problem statement and then using the rather unconventional headings of "this is what I did", and "this is what I saw". He closed his report by using the heading "in conclusion". Nicolas's report format seems to indicate a degree cf creativity and originality. Rachel (intermediate score on opinionnaire) used the more conventional headings of problem statement, background information, hypothesis, design, and observations. However, in concluding her report she connected it to her hypothesis statement by using the heading "accept hypothesis". This also shows some originality. Elaine (low score student on opinionnaire) was most conventional in using the headings of problem statement, hypothesis, design, organization of data, and conclusion.

Science Opinionnaire Response Data

The detailed statistical analysis of students' Likert Scale responses to the opinionnaire are given in Appendix K. This analysis gives the percentage of students, at each grade level, responding to the five statement response choices of strongly agree, agree, undecided, disagree and strongly disagree. It also provides the mean response and standard deviation for each opinionnaire statement. For purposes of these statistical calculations it was necessary to place a numerical weighting on the response choices. The response that was considered most favorable to laboratory activity, by the researcher, was given a weighting of 5, whereas the response that was considered least favorable was given a weighting of 1.

Appendix K also includes a summary of the responses to question 30 of the opinionnaire. This question, as indicated in Appendix C, is open-ended and required students to complete the statement "I think science laboratory work is". At each grade level the response of the 3 selected students to question 30 is identified for comparative purposes.

Response categories in opinionnaire data. The Likert data presented in Appendix K can be related to the research problem more meaningfully by clustering the 29 items in the opinionnaire. Two clusters of statements were identified as shown in Table 4, namely The Nature of Laboratory Activity and the Impacts of Laboratory Activity. The "Nature of Laboratory Activity" cluster includes items pertaining to organization of laboratory activity, the three phases of laboratory activity, and interaction dynamics in the laboratory. The second cluster of "Impacts of Laboratory Activity" takes into consideration statements related to the effect of laboratory activity on learning science, and students' attitudes towards laboratory work and school science. It can be seen that the majority of opinionnaire statements fall into the "Impacts of Laboratory Activity" category.

Table 4 summarizes the student percentage responses for the opinionnaire statements. For purposes of this

TABLE 4

SUMMARY OF STUDENT PERCENTAGE RESPONSES FOR OPINIONNAIRE

Opinionnaire Statements	Arvedson (Gr. 7)			Chadwick (Gr. 8)			Aston (Gr. 9)		
	%A	%U	%D	%A	%U	%D	%A	%U	%D
Nature of Laboratory Activity (Cluster 1)									
4. What we do in class is what a real scientist would do	45	35	20	24	24	52	28	27	45
21. I get actively involved in performing the laboratory experiments	40	25	35	72	12	16	73	14	13
22. Most students discuss their data and findings within their laboratory groups	55	30	15	68	8	24	73	27	0
23. The members within my lab groups do the labs without getting into arguments	35	25	40	68	8	24	63	23	14
25. Working with lab partners helps me to understand the experiments better	70	15	15	72	12	16	86	9	5
26. Pre-laboratory discussions are helpful	85	15	0	84	8	8	100	0	0
27. Laboratory experiments should not have so many instructions	30	25	45	20	36	44	14	27	59
28. Without post-laboratory discussions experiments would be a waste of time	50	35	15	72	16	12	73	4	23
29. Teachers provide students with too much help during laboratory activities	15	25	60	4	20	76	0	23	77

TABLE 4 (Cont'd)

Opinionnaire Statements	Arfvedson (Gr. 7) %A	Arfvedson (Gr. 7) %U	Arfvedson (Gr. 7) %D	Chadwick (Gr. 8) %A	Chadwick (Gr. 8) %U	Chadwick (Gr. 8) %D	Aston (Gr. 9) %A	Aston (Gr. 9) %U	Aston (Gr. 9) %D
Impact of Laboratory Activity (Cluster 2)									
1. Reading science is difficult	45	25	30	28	24	48	18	14	68
2. Spend too much time doing experiments	0	10	90	4	12	84	0	4	96
3. Learning a lot in science	70	25	5	88	12	0	77	9	14
5. Study today's problems in class	15	50	35	36	36	28	32	41	27
6. I dislike coming to science	15	30	55	16	20	54	27	18	73
7. Read more science now than in sixth grade	75	5	20	84	8	8	95	0	5
8. I enjoy doing the science experiments	80	15	5	84	8	8	95	5	0
9. I can solve problems better than before	80	20	0	68	28	4	82	9	9
10. My friends enjoy doing science experiments	55	35	10	56	32	12	32	54	14
11. What I learn in science will be useful outside school	50	30	20	48	40	12	68	18	14
12. Think about what is learned in science when not in school	45	30	25	16	24	60	54	23	23
13. Do not want to take more science than I have to take	45	25	30	36	40	24	18	27	55
14. Reading science is more fun than it used to be	50	35	15	16	20	64	50	27	23
15. Experiments are hard to understand	45	10	45	0	20	80	4	32	64
16. Science is dull for most people	55	25	20	28	40	32	32	50	18
17. The things we do in class are useless	0	25	75	4	16	80	0	9	91

TABLE 4 (Cont'd)

Opinionnaire Statements	Arfvedson (Gr. 7)			Chadwick (Gr. 8)			Aston (Gr. 9)		
	%A	%U	%D	%A	%U	%D	%A	%U	%D
Impact of Laboratory Activity (Cluster 2)									
18. The kinds of experiments I do are important	50	50	0	64	20	16	68	32	0
19. I learn a lot from doing my science experiments	85	15	0	64	24	12	86	5	9
20. Most people like science classes	15	50	35	32	40	28	18	50	32
24. I enjoy working with my lab partners	85	5	10	56	12	32	91	9	0

Note. %A = percentage of students agreeing with statement %U = percentage of students undecided
%D = percentage of students disagreeing

summary the opinionnaire response choices of strongly agree and agree were combined and are shown as percentages for agree. Similarly the opinionnaire response choices of disagree and strongly disagree are combined and shown as percentages for disagree. In the presentation of opinionnaire results which follow, a chi-square analysis of responses is also given whenever significant values were obtained. The chi-square analysis was used to ascertain differences in responses between the grade levels.

Several aspects for the cluster of Impacts of Laboratory Activity are revealed by an inspection of Table 4. It is shown that 90% of grade 7 students, 84% of grade 8 students, and 96% of grade 9 students disagreed with statement 2 "we spend too much time doing experiments." The only students who agreed with the statement were 4% of the grade 8 class. This indicates that most students were either satisfied with the number of laboratory investigations being done (about half of the course at each grade level) or they want more laboratory work, but definitely not less. This was still true even in grade 9 where most students were exposed to laboratory work for a third year. Even though students frequently did recipe-type investigations, a considerable number of students maintained in statement 18 that the "kinds of experiments performed were important" (percentages of 50, 64, and 68 for grades 7, 8 and 9).

Not all students enjoy working with their lab partners. As indicated in Table 4, 10% of grade 7 and 32% of grade 8 students disagreed with statement 24, "I enjoy working with my lab partners." It should be noted that in grade 7, where the largest percentage of students indicated that arguments occurred during laboratory work (statement 23) nevertheless 85% of the students still enjoy working with their lab partners (statement 24). In grade 9, where the lowest percentage of students indicated that arguments occurred (statement 23) 91% of the students enjoyed working with their laboratory partners. Only in grade 8 where 24% of the students indicated that disagreements occurred during laboratory activities is the percentage of students who enjoyed working with their laboratory partners rather low (i.e. 56%). A chi-square analysis of the grade 7 and 8 responses indicated that significantly more grade 7 than grade 8 students enjoyed working with their lab partners (chi-square = 4.36, df= 1, $p \leq 0.0365$). Similarly, a chi-square analysis of grade 8 and 9 responses indicated that significantly more grade 9 than grade 8 students enjoyed working with their lab partners (chi-square = 7.13, df=1, $p \leq 0.0081$).

Most students found class discussions within a pre-laboratory phase to be helpful, as indicated in statement 26 (percentage responses of 85, 84, and 100 at grades 7, 8, and 9 respectively). A chi-square analysis of student responses revealed that significantly more grade 9 students than grade 7 or 8 students found pre-laboratory discussions helpful (the chi-square = 3.55, df=1, $p \leq 0.0590$ and chi-square = 3.85, df=1, $p \leq 0.0492$ respectively). The greater complexity of grade 9 experiments compared to those of grades 7 and 8 may offer an explanation of why all students in grade 9 found the pre-laboratory discussion to be helpful. Nevertheless, pre-laboratory discussions appear to serve a useful purpose for students at all three grade levels.

Post-laboratory discussions are also considered important by students. In fact many students, according to statement 28, were willing to go so far as to say that laboratory work would be a waste of time without post-laboratory discussions (50%, 72% and 73% in grades 7, 8 and 9 respectively). A large percentage of the grade seven class (35%) were in an undecided category.

A rather small percentage of students, as shown in statement 27, agreed that laboratory experiments should have fewer instructions to allow students to think more for themselves (30% grade 7, 20% grade 8, and 14% grade 9). Although a significant number of students are undecided, the majority at each grade level seem to prefer experiments that have an externally imposed structure. In grade 9 where investigations are generally more complex there is the strongest call for a structured type of laboratory work format (i.e. 59%).

Students felt that most laboratory partners discussed the data which they collected. According to statement 22, 55% of grade 7 students agreed that "most students discuss their data and findings within their laboratory groups" compared to 68% in grade 8 and 73% in grade 9. Perhaps increased experience in performing of laboratory activities is again having an influence. As shown by statement 25, students at all three grade levels believe that working with their lab partners often assisted them in getting a better understanding of experiments and their interpretations (70% for grade 7, 72% for grade 8, and 86% for grade 9). Having a laboratory partner(s) is definitely seen by a majority of students as serving the function of peer teacher during laboratory work.

Statement 29 responses showed only 15% of grade 7, 4% of grade 8, and no students in grade 9 agreed that teachers provided students with too much help during laboratory activities. In a chi-square analysis it is shown that significantly more grade 7 than grade 9 students agreed that teachers provided them with too much help (chi-square $= 3.56$, $df=1$, $p \leq 0.0590$). However, students in grade 7 usually are expected to receive more teacher assistance because of their lack in experience with laboratory equipment and techniques.

Responses to question 30. A summary of edited responses to Question 30 of the opinionnaire is given in Appendix K. These responses are categorized in Table 5 along with the numbers which were assigned to student opinionnaire responses to maintain anonymity.

Table 5 shows that 9 students in grade 7, 13 students in grade 8, and 14 students in grade 9 gave a positive response to question 30 with respect to the impact of laboratory activity. This is illustrated by the following student comments:

1. I think science laboratory work is very important. It teaches you to think out problems and to use your head. It is very fun and exciting because you learn and see things you have never heard of. (student number 7, grade 7)

2. I think science laboratory work is interesting and you learn a lot from it. I think that experiments help you understand better what you are studying. (student number 13, grade 8)

3. I think science laboratory work is more interesting and keeps me awake rather than listening to boring discussions and reading all the time. When you actually perform an experiment you get more out of it than just listening to someone talk about it. It is easier to remember things about it when you actually do it. (student number 8, grade 9)

Some of the comments made reflected positively on the nature of laboratory activities (2 students in grade 7, 4 students in grade 8, and 3 students in grade 9). The following student statements serve as examples:

1. I think science laboratory work is the best possible way to learn. People tend to remember things more from first hand experiences than from reading. Conducting an experiment also allows you to ask others to help you understand or vice versa. (student number 16, grade 7)

2. I think science laboratory work is fascinating and intriguing. You discover and learn so much about the world, universe and things that you've never thought of before. Lab work lets you experience things that scientists study and it helps you to have a better understanding of what is happening around you today. (student number 18, grade 8)

However 9 students in grade 7, 5 students in grade 8,

TABLE 5

SUMMARY OF STUDENT RESPONSES TO OPEN-ENDED OPINIONNAIRE QUESTION (#30)

I think laboratory work is"..........

Summary of Student Responses	Related Student Number Grade 7 N = 20	 Grade 8 N = 25	 Grade 9 N = 22
Impact of Laboratory Activity			
-It helps to understand scientific ideas better.	13	3, 10, 11, 12, 13, 24	1, 7, 9, 11, 17 19, 22
-Interesting and fun, generally helps you to learn something new.	5, 7	2, 4, 8, 14, 21	2, 3, 12, 20
-Useful, now and also for the future.	4, 6, 8, 17, 18 20	1, 9	6, 10, 21
-Interesting but not too helpful for the future.		6, 15, 19	
Nature of Laboratory Activity			
-Good, but sometimes its really hard.	1		
-Good, it lets you see what is happening through first-hand experience.	14, 16	7, 16, 18	8, 15, 18

TABLE 5 (Cont'd)

Summary of Student Responses	Related Student Number Grade 7 N = 20	 Grade 8 N = 25	 Grade 9 N = 22
Nature of Laboratory Activity			
-O.K. but some of the experiments are not interesting.	2, 3, 11, 12, 15 19	5, 17, 22, 23, 25	4, 5, 14, 16
-Okay, but I like to work by myself, lab partners are a nuisance	[illegible]0		
-A fun way of doing science with a group of friends you enjoy working with.		20	
-Dangerous	9		

Note. One Grade 9 student did not provide a response #13.

and 4 students in grade 9 chose to respond somewhat negatively toward the nature of laboratory activity. Examples from Appendix K assist in exemplifying this negative viewpoint:

1. I think science laboratory work is more involving of the kids, but sometimes the experiments are so boring, like watching water rise in a tube. (student number 19, grade 7)
2. I think science laboratory work is boring at times, yet interesting at other times. We study boring useless stuff. I mean who really cares how crystals form? A large percentage of the information I learn will never help me in the future at all, not one bit. (student number 15, grade 8)

Teacher Interviews

The collated and categorized interview information from teachers is summarized in Appendix M. These summaries are organized under topic headings and include an abbreviated interview statement relative to the topic from each of the teachers.

A tabulation of teacher interview statements for the nature and impact of laboratory activity are provided in Tables 6 and 7. These two tables provide an interview summary statement and then an inferred teacher response in terms of agree, disagree or no response. This assists in making teacher interview statements easier to compare.

According to Table 6, statement 2, all of the teachers agreed that laboratory work should consist of a pre-laboratory, laboratory, and post-laboratory phase. These phases were seen as breaking the laboratory work into manageable stages, each of which has a definite function

TABLE 6

SUMMARY OF TEACHER INTERVIEW RESPONSES FOR NATURE OF LABORATORY ACTIVITY

	Inferred Responses As Indicated By Teacher Initial Surname		
	Agree	Disagree	No Response Cited
1. Using scientific processes helps to put an order to laboratory work.	S,D,P		
2. The structure of pre-lab, lab and post-lab breaks the laboratory activities into neat divisions.	S,D,P		
3. Pre-laboratory discussions are useful for emphasizing safety, and clarifying what is to be done during laboratory investigations.	S,D,P		
4. Post-laboratory discussions relate how the investigations fit into the concepts being studied, they tie the laboratory work and theory together.	S,D,P		
5. Students are grouped for laboratory work in terms of where they have chosen to sit.	S,P	D	
6. Teacher demonstrations are used primarily as a motivational device, an excitement builder, or as a matter of convenience (i.e. lack of materials, need for use of fume hood).	S,D,P		
7. Open ended investigations probably could not be used effectively as a daily routine.	S,D,P		
8. Use laboratory exams to assess students' laboratory skills.	S,P	D	
9. Need to gather and set out equipment and materials for student laboratory activities.	S,D,P		

TABLE 6 (Cont'd)

	Inferred Response As Indicated By Teacher Surname Initial		
	Agree	Disagree	No Response Cited
10. Often what will be assigned for homework in a laboratory situation is writing-up of the investigation.	S,D,P		
11. Laboratory work is frequently illustration or verification.	S	P	D
12. Laboratory work should be interspersed with other teaching techniques.	S,D,P		
13. It is desirable to have students engaged in writing of some laboratory reports.	S,D,P		
14. Students are usually prepared for laboratory activities solely through in class pre-laboratory discussions.	S,P	D	
15. Equipment and materials are set out or stored in specified locations within the room so that students can acquire and return it as required.	S,D,P		
16. Laboratory work requires more teacher effort than use of other instructional methods.	S,D,P		
17. Students are required to assemble as much of the needed apparatus as possible.	S,D,P		
18. A large student-teacher ratio makes it difficult to give individual attention to all students during laboratory work.	S,D,P		

TABLE 6 (Cont'd)

Summary Statements	Inferred Response As Indicated By Teacher Surname Initial Agree	Disagree	No Response Cited
19. Some assessment of student performance is made during laboratory work.	S,D,P		
20. Student involvement during pre- and post-laboratory discussions is encouraged.	S,D,P		

Note. S = Mr. Scheele, grade 7 teacher, Arfvedson Junior High School
D = Mrs. Dalton, grade 8 teacher, Chadwick Junior High School
P = Mr. Priestley, grade 9 teacher, Aston Junior High School

and is of assistance to students in understanding the processes, techniques, and scientific concepts being taught. When Mrs. Dalton was asked if these three phases were used in all laboratory work being done, the following response was given:

> I never do a lab without discussing it before and after. After sometimes does not come until I have handed back their work, if I have taken it in, because it has more meaning if they have it in front of them. I just feel it is useless otherwise.

Two major activities planned for in a pre-laboratory phase are student exercises and class discussions. Worksheets, reading of the textual materials, and developing necessary initial steps in preparing laboratory reports are some of the planned student exercises. Class discussions are designed, for instance, to emphasize safety precautions, clarify what is to be done in an investigation, demonstrate required procedures and techniques, and review relevant background information (Table 6, statement 3). With reference to pre-lab class discussion Mr. Priestley put it this way:

> One of the very important aspects of pre-lab is emphasizing safety. I don't mind repeating myself every experiment to drum in the safety aspects because I think that is one of the important things when they go on to chemistry 10, 20, and 30, or any of the science courses. In the pre-lab we do a lot of structuring, just nailing down exactly what it is they are going to do, and how this particular experiment relates to the concepts. Sometimes, they forget the major concept that we are investigating; for instance, they get stuck in on separating iron filings from the mixture and forget the concept we are focusing on. We try to put the tree into the forest sort of thing, so that they see the whole picture and that they are just working on the little parts of it.

Post-laboratory phases are organized so as to allow students to complete their laboratory reports, or answer provided interpretation questions. Class discussions which follow are used, for instance, to rectify any student misunderstandings, discuss students' results, tie the theoretical learning and laboratory work together and provide everyday applications of concept(s) studied (Table 6, statement 4). In Mr. Priestley's words post-laboratory discussions are:

> Sort of where we wrap up and show how this fits in, and then we would look for practical applications in everyday life and how this might be used.

Although the teachers consider open-ended inquiry useful and use it sometimes, they seem to feel that it cannot be employed as an ongoing daily activity (Table 6, statement 7). Lack of student background is generally cited as a major reason for this. Consequently, open-ended inquiry is usually limited to simple problems, or as a culmination to a topic or unit of work where students can draw upon knowledge obtained from prior investigations. This implies that structured investigations comprise a considerable portion of the laboratory work being performed. Mr. Scheele expresses this general feeling toward open-ended inquiry:

> I never found that open-ended stuff to work with these kids. Like for 5-10% of your kids it does, but for the majority of junior high school kids it's just a waste of time. They just get lost, they have no reference points, you as a teacher are running around trying to answer all sorts of questions.

Many different teaching techniques are incorporated within these classrooms to assist students with their learning (Table 6, statement 12). Some of the techniques used are teacher demonstrations, giving of notes, using audio-visual materials, lecturing, field trips, seat work (e.g. reading, worksheets, etc.), projects and class discussions. With laboratory activities composing approximately 50% of the course at each grade level, other teaching techniques are being used in the remainder of the course. When asked why methods other than laboratory activities were used, these replies were obtained:

Dalton: For variety, to assist different students, in other words to give everybody an equal chance.

Scheele: For variety reasons, the more different ways you can teach something, I think the better off you are. Lab work is a nice break, the kids are then ready to take notes occasionally, or willing to answer questions, or see a movie. It just breaks things up nicely, it's a variety.

All three teachers agreed that students should be required to prepare laboratory reports (Table 6, statement 13). The number and extent of reports prepared varied with the teacher. Nevertheless, laboratory reports were seen as providing such benefits as practicing additional scientific process skills, improving writing skills, requiring students to be more independent, and increasing the level of student inquiry (due to a removal of some structuring). This is exemplified in a statement made by Mrs. Dalton:

> I think it helps them to organize themselves. I know as a student myself when I learned to write a lab

> report I also learned a lot about essay writing for example. Stating your intentions and summing up things that happened, really helps them that way. It also helps in learning their process skills. If they have to identify the problem, if they have to pick out variables then they are learning something about the scientific processes and why they are doing it. If they don't know why they are doing it then they are just putting in time.

Table 7 shows how the interviewed teachers see laboratory activities assisting students in the learning of science. Three statement in particular should be noted. Firstly, with laboratory activities students are involved in seeing, doing, or finding out for themselves. This personal involvement broadens the scope of observed happenings, and therefore increases the possibility in being able to recall that which occurred (Table 7, statement 1).

Priestley: I firmly believe in the saying, I see and I remember little, but when I do I remember more, or something to that effect. I think for many of the kids this is very true, when they manipulate and actually do the experiment themselves it has a longer lasting effect, their retention is greater.

Secondly, while engaged in laboratory activities most students displayed some degree of eagerness. A desirable spin off from increased eagerness is increased interest and learning. Consequently, laboratory work can act as a motivational device in the learning process (Table 7, statement 2).

Scheele: If it wasn't for the motivational aspect I don't know if I would do lab experiments or not, because they are a hassle. But it does motivate the kids.

Thirdly, students at the junior high school level often

TABLE 7

SUMMARY OF TEACHER INTERVIEW RESPONSES FOR IMPACT OF LABORATORY ACTIVITIES

Summary Statements	Inferred Responses As Indicated By Teacher Surname Initial		
	Agree	Disagree	No Response Cited
1. Lab work has a longer lasting effect on retention rate.	S,P		D
2. Lab work helps to motivate students.	S,D,P		
3. The abstract is reduced to the concrete during laboratory activities.	S,D,P		
4. Students become more scientifically literate through performing experiments.	S,D,P		
5. Doing lab work provides a variation in learning style.	S,D,P		
6. In performing laboratory investigations students develop social skills, such as learning to work with others, and also improve their basic organizational skills.	S,D,P		
7. Lab reports help to improve students' writing skills.	D,P		S
8. Involving students in laboratory activities gives them a chance to see what they can come up with (feeling of independent work).	S,D,P		

TABLE 7 (Cont'd).

Summary Statements	Inferred Responses As Indicated By Teacher Surname Initial Agree	 Disagree	 No Response Cited
9. Provides for direct application of scientific processes.	S,D,P		
10. Some students probably find open-ended investigations (high level inquiry) frustrating.	S,D,P		

Note. S = Mr. Scheele, grade 7 teacher, Arfvedson Junior High School
D = Mrs. Dalton, grade 8 teacher, Chadwick Junior High School
P = Mr. Priestley, grade 9 teacher, Aston Junior High School

have difficulty understanding theoretical concepts. Many of them do not have a base of experience needed to think abstractly about new ideas. Laboratory experiments provide assistance by reducing the abstract to the concrete, that to which students are capable of relating because they can see it happening. This reduction from abstract to concrete provides students with the experience necessary for learning to occur (Table 7, statement 3).

> Dalton: A lot of kids, because you have a variety of developmental levels, need to see in order to understand, need to manipulate in order to understand. So it helps especially those children.

Student Interviews

The interviews with nine selected students are collated and categorized in Appendix N. Interview topic headings are used to organize this Appendix. Each student's response is provided in a summary format. This is done on the basis of student interviews at each school. Summarizing student interviews under interview topic headings allowed for easier comparison of responses.

Table 8 summarizes student interview statements pertaining to the nature of laboratory activities. The responses for the nine students interviewed (three at each grade level) are included. General statements were made of student responses and individual student categorization into agree, disagree, or no response was based upon either direct or indirect responses made by students during interview discussions. Some of these summary statements

TABLE 8

SUMMARY OF STUDENT INTERVIEW RESPONSES FOR NATURE OF LABORATORY ACTIVITIES

Summary Statements	Inferred Response As Indicated by Initial of Student's Name		
	Agree	Disagree	No Response Cited
1. Laboratory work is doing experiments.	K,J,O		
	M,A,I		
	N,R,E		
2. Pre-laboratory activity helps in understanding	K,J,O		
	M,A,I		
	N,R		E
3. Prefer to have laboratory investigations which are structured	K,J	O	
	M,A,I		
	N,R	E	
4. Series of questions included in investigations are helpful in increasing understanding	K,J	O	
	I	A	M
	N,E	R	
5. Would rather do laboratory reports than the questions at end of experiments	K,J,O		
	A,I	M	
	N,R,E		
6. Even in experiments where the answers are known before hand, lab work helps to obtain a better understanding	K,J,O		
	M,A,I		
	N,R,E		

TABLE 8 (Cont'd)

Summary Statements	Inferred Response As Indicated By Initial Of Student's Name		
	Agree	Disagree	No Response Cited
7. Post-laboratory discussions assist in realizing the purpose of doing experiments	K,J,O M,A,I R,N,E		
8. Would not like to do laboratory work by myself.	K,O M,A,I N,R,E	J	
9. Often experiments requiring the use of your senses are more interesting than getting readings from instruments.	K,J,O R	N	M,A,I E
10. Having open-ended investigations once in a while can be interesting and helpful.	K,J,O M,I N,R,E		A
11. Prefer more experiments, less writing of notes, reading etc.	K,J,O M,A,I N,R		E
12. My laboratory group partners sometimes get into disagreements while performing experiments.	O E	K,J M,A,I R,N	
13. Teachers help students too much during laboratory activities.	O	K,J M,A,I N,R,E	

TABLE 8 (Cont'd)

Summary Statements	Inferred Response As Indicated By Initial of Student's Name		
	Agree	Disagree	No Response Cited
14. My laboratory group partners assist each other to understand the experiment.	K,J,O M,A,I N,R,E		
15. Students like to have the teacher come around to their laboratory tables while doing experiments.	K,J M,I N,R,E		O A
16. I read through the laboratory experiment before performing it.	K,J M,A,I R,E	O	N
17. Would rather manipulate materials and equipment during laboratory work than watch my laboratory group partners perform.	K,J,O M,A N,R	I	E
18. Most of what is learned in science (including laboratory work) has application to every day situations.	K M N,R,E	J,O A,I	
19. Students like to be involved in assembling and constructing needed laboratory equipment.	K,J,O M N,R		A,I E

TABLE 8 (Cont'd)

Summary Statements	Inferred Response As Indicated by Initial of Student's Name Agree	Disagree	No Response Cited
20. Laboratory work is like a "play" period.	K	J,O N,R	M,A,I E
21. Like to have all laboratory group partners involved in doing experiments.	K,J,O M,A,I N,R		E
22. During post-laboratory discussions there could be more student involvement.	J,O R,N	K	M,A,I E
23. In pre-laboratory discussions do not want to be told everything, want to have a challenge.	K,J,O M,A N	I	R,E

Note. K = Karl (high attitude), J = Jacob (intermediate attitude), O=Olaf (low attitude)
(Grade Seven Students Arfvedson Junior High)
M = Marie (high attitude), A = Alfred (intermediate attitude), I=Irene (low attitude)
(Grade Eight Students Chadwick Junior High)
N=Nicolas (high attitude), R=Rachel (intermediate attitude), E=Elaine (low attitude)
(Grade Nine Students Aston Junior High)

will be dealt with presently.

Eight students felt that pre-laboratory activities assisted them in understanding investigations better (Table 8 statement 2). The ninth student was absent when this discussion occurred. Students felt that the pre-lab activities helped them when teachers explained the basis of an experiment, demonstrated use of needed apparatus, clarified instructions, outlined what basic outcomes to expect, and pointed out precautions. Most students also indicated that they might be able to perform some investigations without a pre-laboratory discussion. Karl, one of the grade 7 students, expressed the need for the pre-laboratory phase this way:

Jeske: For question 26 of the opinionnaire which reads, "class discussions and demonstrations before the laboratory are helpful" you gave the response of strongly agree. How do you feel about the pre-labs?

Karl: Yeah, they really help.

Jeske: In what way?

Karl: In the books there is a lot of detail most places, yet it is sometimes difficult to take something out of the book and apply it to that which you are actually doing. We also have had others labs; our teacher told us the proper way to conduct certain lab activities. For example, boiling water and doing things slowly. And the teacher sort of coming back to this and reminding us not only helps us to be able to be more united, as far as being able to get together by no one making any mistakes, but it could also prevent some accidents that may happen.

All of the students agreed that post-laboratory discussions also provided assistance in understanding investigations (Table 8, statement 7). The post-lab was seen as being helpful since it reviewed what happened, explained why something happened, allowed students to ask questions, clarified the purpose of investigations, and provided opportunities to discuss with others. This was illustrated during a conversation with one of the grade 9 students:

Jeske: Question 28 of the opinionnaire says, "Without classroom discussions after the laboratory, experiments would be a waste of time". Your response was strongly agree, why did you say this?

Nicolas: You might just do it, do your laboratory experiment, and right after you finished don't talk about it, and don't do anything, then you just forget about it.

Jeske: So how does the post-lab discussion help?

Nicolas: So if you go right through it again you will fully understand what you are doing.

Five of the interviewed students indicated that the post-lab activity of answering a series of provided inference questions helped them to understand better (Table 8, statement 4). A typical grade seven student response was:

Jeske: Do you like doing the series of questions provided in the investigation (e.g. Life Science Book)?

Karl: They sort of follow up to the experiment and it is good because it makes you review. It makes you think back to what you actually did do, so that it wasn't just some guy slacking off or whatever, and was just having fun doing the experiment. And that is probably the best part about the learning, reviewing the work.

An opposite point of view expressed by three students indicated that some of the provided inference questions were too easy, others were too difficult and did not relate directly to the experiment performed. Excerpts from a conversation with a grade 7 student illustrate the opposition expressed toward provided inference questions.

Jeske: Do you like doing the series of questions provided in the investigations?

Olaf: No.

Jeske: Why not?

Olaf: Well some of them I can't get.

Jeske: Would you like to do lab reports instead of questions?

Olaf: Yeah.

Jeske: Why do you think you might want to do lab reports?

Olaf: Well, it's easier because questions you have to think for a while and if you don't get it, then you just don't get it, but for the lab report you just think of things and you write them down as you are thinking them.

Olaf, a grade 7 student, and Elaine, a grade 9 student, indicated that lab group partners sometimes got into arguments while performing experiments. Olaf's comments:

Jeske: Question 23 of the opinionnaire said "the members within my lab group do the labs without getting into arguments", and you responded with strongly disagree. Are you telling me that your lab partners do sometimes argue with each other?

Olaf: Yeah.

Jeske: Could you tell me about this?

Olaf: One says I want to do this, and another says I want to do that.

Jeske: So you can't agree with each other how you are going to do the experiment. What finally happens?

Olaf: One of us finally does whatever he wants.

Jeske: One of you does whatever he wants?

Olaf: We finally agree.

Elaine responded as follows:

Elaine: Someone is doing the experiment or whatever and they mess it up, then everyone gets mad at that person.

Jeske: Why do they get angry when someone blows the experiment?

Elaine: I guess because you have to start all over again.

Although both of these students had some disagreements within their laboratory groups, it appeared that they were usually capable of working it out. Perhaps Olaf's group would be the harder of the two groups to work in, since it apparently took some additional time in each experiment to get agreement between group members on what needed to be done, and who was going to do it.

Karl worked with partners that usually did not get into arguments. A discussion with Karl revealed why their group members were able to work together:

Jeske: Do you ever sort of say to each other, no that is not the way to do this, or I know how to do it but you don't, or get into a little argument about how you should do the experiment?

Karl: Most of the time it is just straight forward. But sometimes there are mistakes. If you just go and yell at them and say that's wrong then they take offense against that and try to defend themselves. But if you walk up to them and

> maybe you can even draw a diagram or something, and show them politely, and say I don't think that's totally right, but you don't condemn them, then they will be more willing to accept that and re-do it correctly.

Student's interview responses regarding the impacts of laboratory activities are summarized in Table 9. These responses are examined for prevailing trends in how students viewed the impacts of laboratory activities. Some of the original statements will be cited in the following discussion for illustrative purposes.

Involvement in laboratory activities apparently engenders a desire in students to want to find out, to discover. Assembling of the apparatus, preparing required materials and then beginning the investigation creates a curiosity as to what is going to happen. As indicated in Table 9, statement 1, all of the students interviewed concurred that laboratory work encourages a desire to find out. This is exemplified in a discussion with Rachel.

Jeske: Did this experiment encourage you to think about, or want to find the answer to the problem?

Rachel: Yeah, it did.

Jeske: How?

Rachel: Well, we had to do it in another period, to finish the experiment and at the end of the first period, we kind of thought we can't wait to see what that is.

As shown in Table 9 (statements 4 and 5), all of the interviewed students who provided a response agreed that doing laboratory work resulted in improvement of their

TABLE 9

SUMMARY OF STUDENT INTERVIEW RESPONSES FOR IMPACT OF LABORATORY ACTIVITIES

	Inferred Response As Indicated By Initial of Student's Name		
Summary Statements	Agree	Disagree	No Response Cited
1. Doing experiments encourages a desire to want to find out.	K,J,O M,A,I N,R,E		
2. Experimenting is the fun part of science.	K,J,O M,A,I N,R,E		
3. Learning something new in many of the laboratory activities.	K,J,O M,A,I N,R,E		
4. Laboratory investigations improve your skills of manipulating or handling of equipment.	K,J,O M,A,I N,R,E		
5. Involvement in performing experiments encourages improvement in observational skills.	K,J,O M,A,I R,E		N
6. Often it is possible to apply what is learned during laboratory investigations to every day situations.	K M N,R,E	J A,I	O

TABLE 9 (Cont'd)

Summary Statements	Inferred Response As Indicated By Initial of Student's Name		
	Agree	Disagree	No Response Cited
7. Lab work allows you to see for yourself.	K,J,O M,A,I N,R,E		
8. Scientific concepts would not be understood as well without doing lab work.	K,J,O M,A,I N,R	E	

Note. K=Karl (high attitude), J=Jacob (intermediate attitude), O=Olaf (low attitude)
(Grade Seven Students Arfvedson Junior High)
M=Marie (high attitude), A=Alfred (intermediate attitude), I=Irene (low attitude)
(Grade Eight Students Chadwick Junior High)
N=Nicolas (high attitude), R=Rachel (intermediate attitude), E=Elaine (low attitude)
(Grade Nine Students Aston Junior High)

manipulative and observational skills. With practice in using laboratory apparatus and materials students became more adept. Students also felt that familiarity with assembling and functioning of laboratory equipment could be learned best through hands-on activities. Watching others or reading about handling laboratory apparatus may be of some assistance, but it is not as effective as actually being involved in manipulating equipment. Students also need to learn how to make careful quantitative and qualitative observations. Improvement in making of these observations only comes with practice as provided during laboratory investigations. Responses given by Alfred and Karl are illustrative of students' viewpoint for these two summary statements.

Jeske: How do most laboratory experiments tend to improve you skills in manipulating of lab equipment?

Alfred: Yeah, it teaches me how to use it more wisely and more cautiously.

Jeske: Now that you have done experiments for almost a year in grade seven, do you think that you look at experiments differently than you did at the beginning of the year in terms of what you see in the experiment?

Karl: Oh, we are more able to dig into the experiment for information as well as now we are more familiar with all the processes. Probably now we are getting into more complicated stuff because we are now able to take on these more complicated things. Where more and more of it is starting to be dependent on us and how we use the processes, the various scientific tools to our advantage.

From Table 9, statement 3, it can be seen that all nine students felt they generally learned new concepts while doing laboratory investigations. With the exception of Elaine, the students also were of the opinion that scientific concepts would not be understood as well without doing laboratory work (Table 9, statement 8). It seems that even when students were primarily engaged in low to medium level inquiry they still felt they were learning new concepts, or reinforcing those for which they only had a superficial understanding. This point of view was shown in a response given by Rachel.

Jeske: Do most of your laboratory experiments indicate or teach you something new, or do you know the answers most of the time before you perform the experiments?

Rachel: No, once I do them then I know the answers, but otherwise I don't unless I see them.

When students engaged in open-ended inquiry, as in investigation 3 in grade 9, they attributed impacts to it such as the following:

1. Provides a challenge.
2. Gives you a chance to show what you can do.
3. Requires considerable cooperation between laboratory partners.
4. Demands the recall of previously learned techniques and concepts.
5. Makes you think.
6. Involves more work in performing.
7. Deals with something significant.
8. Creates excitement and enjoyment.

Three student interview excerpts are provided for illustrative purposes:

Jeske: Did this investigation challenge you more than the regular type of investigations?

Nicolas: Oh yeah.

Jeske: In what way?

Nicolas: You had to do a lot more work, it dealt with something more significant. I had to do more than I did with the other ones. I had to do a whole bunch of things just to find one thing.

Jeske: Do you feel confident that you understand the purpose of doing this particular experiment?

Rachel: Yeah.

Jeske: Why do you feel that way?

Rachel: I don't know, it's just because I know that I kind of did it and figured things out myself without having to read something, and by saying we'll do it this way.

Jeske: Why do you think this investigation was more challenging?

Elaine: Because it is there and you have to try and get everything out of it, identify it. Like we didn't quite know how to separate them, as we had to figure out ways on our own from those that we learned before, bring them all back and figure each one.

Data From the Pre- and Post-Laboratory Discussions

Taped pre- and post-laboratory discussions for each grade level are summarized in Appendix O. Classifying the class discussions allowed for comparison of discussions for different investigations at the same grade level and for comparisons of discussions which occurred at the different grade levels.

Pre-laboratory discussions. During pre-laboratory discussions safety precautions in performing the laboratory investigations were of utmost importance to each of the teachers. For instance in grade 9, when Mr. Priestley introduced Investigation One, Distinguishing Between Elements By Flame Tests, students were provided with the following precautions:

> Don't attempt to taste the chemicals, I am sure you won't, but you may get some on your fingers and then put them into your mouth. You'll have to remember to keep your fingers away from your mouth. In fact try not to get the chemicals on your hands because some of them are absorbed through the skin.

Demonstrating or reviewing use of laboratory equipment and techniques was also perceived by the teachers as being an essential aspect of organizing for students to perform laboratory investigations. Students at the junior high school level frequently have not used the required apparatus previously, or have only used it occasionally so that a review of its use is necessary. In addition, emphasizing the proper use of equipment provides a better guarantee that apparatus will not be mishandled and may also provide for better collection of data. An introduction to zero balancing a triple beam balance was provided by Mrs. Dalton in the grade 8 class during the pre-laboratory discussion for Investigation One, Using Relative Density To Identify Minerals.

> To zero balance you turn this knob back here (shows students knob on the balance). For obvious reasons you know this is called a triple beam

> balance, it has three beams. We call these things riders, (points to riders) each one is calibrated differently 100 g, 10 g, 0.1 g. When we say to zero the balance what we mean is turn this knob, with all the riders to the left, until this pointer (shows students the pointer) points to zero.

Review of experimental designs was seen as an important part of pre-laboratory discussions. Going through the steps to be performed by students during an investigation clarifies some misunderstandings that may exist. This may free the teacher to make observations of students' efforts and allows for some conversation with students while performing the experiment. It may also ensure that most students perform an outlined investigation in the required manner. The extent of design explanation is dependent upon grade level and complexity of investigations being done. An illustration of design explanation was shown by the intern teacher at Arfvedson Junior High (clarifying of step E in Investigation Two):

> This is the step where I will have a test tube of alcohol. There will be a beaker placed on your desk, you are going to take the leaf and swirl it into hot alcohol. The alcohol will also be sitting in a larger beaker with hot water in it. The only time you are going to light the bunsen burner is when you are going to boil the water with the leaf in it. The alcohol is not coming out until after we have boiled the leaf in water for 3 minutes.

Pre-laboratory discussions also provided students with practice or review. Without this some students might not have been able to deal successfully with some parts of an investigation. This was exemplified by Mrs. Dalton in providing students with a worksheet to practice the calculations for relative density:

> Let's just do an example now. Write the problem down and then I would like you to try and work it out. I'll make the numbers easy to work with. (Problem is written on chalk board). I also have seven problems here (on a worksheet to be handed out) which I would like you to try.

Post-laboratory discussion. The post-laboratory phase involves students in dealing with scientific processes such as graphing, treating data mathematically, making inferences, seeking further evidence, examining new problems, and application of discovered knowledge. The extent of student involvement in using these scientific processes during this phase of the laboratory work, varied from students answering provided questions to preparing laboratory reports as indicated below.

> Priestley: The last experiment in this series is not written up for you. You have to write it up yourself using all of the processes, or as many processes as are appropriate to use. What I am going to do is give you a mixture, I am not going to tell you what is in it. You can use the techniques you have used for separations to separate them. It is not just a matter of separating them, but also trying to identify what the materials are.

After students had completed their laboratory reports, or answered the series of provided questions they were sometimes required to hand in their work for marking by the teacher. This served as a means of assessing students' achievements for report card purposes, as well as giving an indication to students of how well they were doing in interpreting data collected during their laboratory work.

Post-laboratory class discussions occurred after students had completed answering the provided inference questions, or after the teacher had marked students' laboratory reports. These post-laboratory discussions usually had three constituents:

1. Discussion of the answers to a series of provided inference questions or a discussion of students' prepared laboratory reports.
2. Answering additional questions posed by students to obtain further understanding.
3. Providing practical applications of scientific concept(s) learned from the laboratory work.

Three excerpts from the post-laboratory discussion in Appendix O are retrieved to illustrate these three elements of post-laboratory discussion. An example of the first constituent was provided by the intern teacher at Arfvedson Junior High in going over answers to inference questions for Investigation One.

Intern Teacher: Question number eight! (teacher reads question). If the white part of the onion contained sugar, how do you think it got there?

Student: (called upon by teacher) By photosynthesis.

Intern Teacher: Not right!

Another Student: (called upon by the teacher) By the process of diffusion.

Intern Teacher: Right.

Intern Teacher: (Repeats answer so that students can write it down if necessary). "By the process of diffusion from the green part of the onion."

During a post-laboratory discussion of Investigation One, Distinguishing Between Elements by Flame Tests, Mr. Priestley and a student got into a discussion which illustrated how students ask questions to obtain a better understanding of observations obtained during laboratory work.

Priestley: If chlorine is giving the color then it will be the same color in copper chloride as in sodium chloride. Chlorine wasn't giving the color. So the copper and sodium are giving the color because chlorine is common to both compounds, so its color should be common.

Student: Why can't it be a combination of both, a combination of the color of copper and of chlorine?

Priestley: Well, if you want to prove that you could try copper oxide, and copper something else in the flame test.

While discussing relative density, Investigation One (grade eight), Mrs. Dalton gave students a practical application of apparent weight loss of an object when immersed in a fluid:

Dalton: You don't actually lose weight, but the water pushes you up and you appear to lose weight. What do we mean by weight loss in water?

Student: How much lighter you are when in water.

Dalton: When you go into a swimming pool it is easy to lift another person because there is a force called the buoyant force acting on you. It counteracts the force of gravity which is weight.

Science Laboratory Interaction Categories (SLIC) Results

SLIC checklist observations are summarized in Appendix P. The student interactions observed at each grade level are collated for the investigations concerned. The summaries provide a summation of the number of times, within each investigation, particular interaction categories on the SLIC checklist were observed for each of the selected students. With a summary of each grade level it is easier to determine the predominant interactions which are occurring for each individual, and to make comparisons between students at the same grade level or between students at different grade levels.

The SLIC checklist was used to observe student interactions during the laboratory phase of lab activities. During each investigation 3 selected students were observed for about 15 to 20 minutes with this instrument. Chadwick Junior High students were observed as they performed two laboratory investigations, while students at Aston and Arfvedson were observed three times.

In Table 10 check marks from SLIC checklists have been translated into percentage of time individual students spent in each science laboratory interaction category. During these observations there was only one category, that of "shows", where no students participated. That is, no students were seen, during investigations observed, manipulating materials for the purpose of showing someone else how to do something or illustrating to them the results obtained. If this occurred, it was very difficult to detect, since it blended in with the required manipulations at the laboratory stations. Students instead probably were using verbal explanations to assist each

TABLE 10

PERCENTAGE OF OBSERVED LABORATORY TIME SPENT BY SELECTED STUDENTS IN EACH OF THE SCIENCE LABORATORY INTERACTION CATEGORIES (SLIC) OVER SEVERAL INVESTIGATIONS

	Grade 7			Grade 8			Grade 9		
CATEGORY	Karl	Jacob	Olaf	Marie	Alfred	Irene	Nicolas	Rachel	Elaine
Shows	0	0	0	0	0	0	0	0	0
Manipulates apparatus, observes activity	54	41	25	51	36	33	40	43	14
Transmits information	1	2	4	3	5	3	10	4	2
Asks questions	3	3	6	0	2	6	9	7	1
Listens	3	3	4	5	4	5	7	5	8
Observes passively	1	7	13	2	6	6	4	8	28
Reads lesson related material	0	0	0	7	6	5	4	3	6
Writes notes or records data	19	20	6	24	20	27	7	8	10
Gets supplies	5	11	14	5	8	11	4	10	9
Non-lesson related behavior	14	13	28	3	13	4	15	12	22

Note. For a more detailed description of SLIC categories and checklist used see Appendix P. Percentages rounded off to nearest whole number.

other.

Olaf, Irene and Elaine did not spend much time manipulating equipment and materials, e.g. experimenting, during observed investigations. There appears to be a relationship between amount of time spent in manipulating materials and how difficult students tend to find experiments. According to Table 10, Olaf and Irene asked more questions, particularly of the teacher, than other students observed at their grade level. It is also shown in Table 10 that those students who were less involved in manipulating materials appeared to generally be more actively involved in getting supplies, a less difficult task, but one which nevertheless still showed a desire for involvement.

Table 10 also indicates that students not actively involved in manipulating equipment and materials seemed to spend more time than other students in passively watching the work or discussions of their laboratory partners. In two cases, that of Olaf and Elaine, more time is given to non-lesson related behavior. That is, there is a tendency for students not manipulating the equipment or materials to wander aimlessly around the room, socialize at other laboratory tables, and begin playing with equipment and materials not being used by their lab partners who are performing the investigation.

A comparison of student time spent in reading lab notes (e.g. the design of structured investigations, etc.)

while doing experiments showed that it is non-existent for grade 7, but definitely noticeable for grades 8 and 9 (See Table 10). This could be rationalized possibly in that grade 7 students do simpler experiments, not only in terms of difficulty but also in length. As a result, students do not have to refer back to their laboratory notes to perform an experiment after the teacher has explained, in the pre-laboratory phase, what needs to be done. Grade 7 and 8 students spent more time recording data and generally in writing notes than grade 9 students. An explanation for this could be that grade 9 experiments are more frequently based on quantitative observations which are easily recorded into a chart prepared in advance. Or, maybe it is dependent upon the type of record that teachers required, lab report as compared to structured laboratory notes. For the particular grade 8 class observed, the latter was the case, since students were often required to prepare their own laboratory reports, which supposedly takes more individual student initiative. However, for grade 7 the first explanation is more applicable because their experimental observations were essentially qualitative which often required additional recording time.

Researcher's Field Notes

A summary of researcher field notes is provided in Appendix G for each school setting (Tables 11-18). The laboratory investigations performed by students at a given school were used as a framework in designing these summaries. For each investigation observed summary notations are provided for the three phases of laboratory activity, if applicable. This design was chosen since it aligns researcher field notes with pre- and post-laboratory discussions, observed laboratory investigations, and students' laboratory reports. It also allows for a comprehensive coverage of the field notes.

From the summary in Appendix G it can be seen that at each of the grade levels a pre-laboratory phase was an essential part of the laboratory activity. The pre-laboratory phase is shown as being used to:

1. Introduce the problem to be examined (Table 18).
2. Read provided background information in class (Table 11).
3. Dictate or write background information for students, including examples and sample calculations (Table 14).
4. Practice needed formulas, relationships, and concepts by means of worksheets (Table 11).
5. Allow students to prepare the pre-laboratory sections of laboratory reports (Table 14).
6. Discuss and/or demonstrate the provided procedure including needed techniques, precautions, and care in handling equipment (Table 17).
7. Review previously learned concepts, mathematical relationships, and techniques as required in an investigation (Table 15).

The field notes indicate that grouping students for the laboratory phase ranged from students forming their own groups by virtue of class location, to the teacher assigning students to laboratory groups. While students were engaged in performing the laboratory investigation, the teacher usually circulated around the room and assisted students as needed. In addition, one of the teachers evaluated student behavior and performance levels as students performed the hands-on portion of the investigation. This is indicated by the following statements from researcher field notes:

1. During lab work teacher circulated around the room assisting students as necessary (Table 16).
2. Regular classroom teacher also came into the classroom to assist students in performing of the investigation (Table 11).
3. Teacher helps students as required. Teacher also evaluates behavior and involvement of students as they perform the experiment (Table 14).

The field notes indicated that post-laboratory activities ranged from students answering provided inference questions, to interpreting collected data for developing inferences or generalizations for laboratory reports. While students worked on processing of their data, teachers generally moved around the classroom monitoring behavior and assisting students as required. This is indicated by two researcher field note notations:

1. Students performed second part of the investigation, with a plant kept in the dark. Students were asked to answer questions for the investigation, and to complete these questions for homework (Table 12).

2. Students completed performing the separation and identification of components in the mixture experiment, and began writing-up their lab reports for this investigation. Students to complete lab reports for homework. During post-lab activities teacher assisted students as required (Table 18).

According to the field notes, the post-laboratory phase served the following functions:

1. Allowing students to answer provided inference questions (Table 13).
2. Allowing students to prepare their laboratory reports (Table 14).
3. Discussing answers to provided inference questions (Table 11).
4. Providing further explanations to assist student understanding (Table 11).
5. Allowing students to ask questions for further clarification and understanding (Table 16).
6. Examining practical applications of concepts studied (Table 16).
7. Discussing laboratory reports after the teacher has marked them (not observed only inferred from teacher comments).

The level of inquiry for laboratory investigation was indicated as ranging from low to high. In some of the investigations observed, the researcher comments showed that the laboratory notes and teachers structured all phases of the laboratory activity (Table 11). In other investigations students were required to develop some aspects of the investigation for themselves (e.g. background information) (Table 14). In still other investigations students were required essentially to develop most aspects of the laboratory activity (e.g. open-ended investigations, Table 18). It was also indicated that both structured investigations and student-developed laboratory reports were organized around the scientific process skills. This is illustrated by a researcher field notes comment:

> A list of the scientific processes is taped to the west wall. Students are to use these in preparing their reports. Students need to develop their lab reports from the problem onward (Table 18).

The time required for laboratory activities to evolve from the pre-laboratory phase to the post-laboratory phase was judged to be from 2 to 5 class periods. This time frame depended on factors such as the amount of pre-laboratory work that was required to prepare students for laboratory work, the length of the laboratory phase, and the degree of student involvement in developing the laboratory activity.

It is interesting to note that during the open-ended investigation in grade 9, student interaction was seen as being very positive, even though this type of activity was not a regular occurrence. This is illustrated by two comments from researcher field notes:

1. Students settled down to work on the investigation relatively quickly within their laboratory groups (Table 8, period 1).

2. Students appeared to work extremely well on performing this investigation (Table 18, period 2).

Summary

Chapter 4 outlines the research setting at each of the schools visited, and delineates the findings with respect to the Nature and Impact of Laboratory Activities as obtained by using the eight data gathering techniques.

Data from researcher field notes, teacher interviews, and taped pre- and post-laboratory discussions showed that laboratory activities at each of the three schools was composed of a pre-laboratory, laboratory, and post-laboratory phase. Each of these phases was shown as fulfilling definite functions during the laboratory activity.

The pre-laboratory phase, as indicated by the researcher field notes, taped pre-laboratory discussions, and teacher interviews fulfilled functions such as providing background information, discussing procedures, outlining safety precautions, acquainting students with laboratory equipment and techniques, and preparing students for laboratory work by providing readings and worksheets.

Student science opinionnaire responses revealed that 85% of grade 7, 84% of grade 8, and all of the grade 9 students who participated in the study found pre-laboratory activities to be helpful. Student interviews indicated that students felt that the pre-laboratory phase helped them to understand what was to be done during the experiment. However most students indicated that they did not want the pre-laboratory phase to provide them with all the information, they wanted the laboratory activity to be challenging.

An analysis of student laboratory reports and observed laboratory investigations indicated that [illegible] of the observed investigations had considerable structure provided by the laboratory manual and/or teacher, and only a fair level of student inquiry. The other three observed investigations varied from moderate to high level student inquiry.

Student responses to the science opinionnaire indicated that 40% of grade 7, 72% of grade 8, and 73% of grade 9 students thought they got actively involved during the hands-on laboratory phase. The science opinionnaire also revealed that 55%, 68% and 73% of grade 7, 8 and 9 students respectively felt that students discussed their data within their laboratory groups. Student interviews and science opinionnaire statements revealed that some students tend to get into arguments with their laboratory partners during the hands-on laboratory phase. From the SLIC checklist it was seen that students who spend less time in manipulation of equipment and materials tended to spend more time in passive observation and non-lesson related behavior.

The post-laboratory phase according to taped post-laboratory discussions, researcher field notes, and teacher interviews allowed for answering inference questions and preparation of laboratory reports, discussion of laboratory reports and inference questions, clarification of misunderstandings, providing practical examples and applications, and tying together of the laboratory work and theoretical concepts.

Student responses on the science opinionnaire showed that 50% of grade 7, 72% of grade 8, and 73% of grade 9 students felt that laboratory activities without a post-laboratory discussion would be a waste of time. The student interviews indicated that post-laboratory discussions assisted them in realizing the purpose of performing laboratory investigations.

Numerous impacts of laboratory activities were portrayed by the student science opinionnaire responses, teacher interviews and student interviews. Some of the indicated impacts for laboratory activity were making science fun, improving manipulative and observational skills, allowing for a better understanding of concepts, creating curiosity, increasing retention rate, improving problem solving capabilities, and illustrating abstract concepts with concrete examples.

CHAPTER 5

DISCUSSION OF RESULTS

This chapter is an interpretation of the findings presented in Chapter 4. Discussion of the results is centered around the questions used in guiding the research study: that is, around the organization of laboratory activities, student interactions during laboratory activities, and outcomes attributed to laboratory activities by students and teachers.

Organization of Laboratory Activities

Three Laboratory Phases

The results indicate that the three phases of pre-laboratory, laboratory, and post-laboratory are central in organizing of laboratory activities at the junior high school level. This is revealed by examining a number of different sources.

Researcher field notes depict the use made of each of these phases during the teaching-learning process (See Tables 11-18, Appendix G). The most frequently noted teacher pre-laboratory activities were:

1. Emphasizing laboratory safety precautions.
2. Demonstrating needed laboratory techniques (e.g. lighting of a bunsen burner, setting up of a filtration apparatus).
3. Explaining the experimental design as provided in the laboratory manual.

4. Discussing background provided by the laboratory manual.
5. Explaining mathematical formulas needed in an investigation, and providing sample calculations.
6. Discussing charts for recording of data.

The most frequent student pre-laboratory activities were:

1. Reading laboratory manual provided background information.
2. Doing worksheet questions.
3. Preparing laboratory reports/notes in preparation for data collection (e.g. hypothesizing, listing of variables, developing charts for data recording).

During the laboratory phase students were engaged in doing the laboratory experiments while the teacher moved around the room assisting laboratory groups which experienced difficulty in performing their experiment. The post-laboratory activities performed by teachers included:

1. Assisting students in preparing their laboratory reports/notes.
2. Discussing answers to laboratory manual provided inference questions (or discussing of student laboratory reports).
3. Answering questions asked by students for further understanding.
4. Providing practical examples of concepts learned.
5. Questioning students to determine extent of understanding.

6. Relating the laboratory experience to the theoretical concept.

Student post-laboratory activities most frequently noted were:

1. Answering laboratory manual inference questions.
2. Preparing laboratory reports after data collection (e.g. mathematical treatment of data, making inferences).
3. Asking the teacher for further explanations during post-laboratory class discussions.

Teacher interview statements are also supportive of employing three laboratory phases. Table 6, statement 2, (p. 127) shows that all of the teachers interviewed agreed that the structure of pre-lab, lab, and post-lab breaks the laboratory activities into neat divisions. This is further illustrated in a conversation with Mr. Scheele.

Jeske: Do you follow the structure of pre-lab, lab experiment, and post-lab in all your lab work, or do you use other structures?

Scheele: It's a structure that we tend to use for much of the lab work, the pre-lab mainly for safety, to make sure kids understand directions, and introducing the concept. Then the actual lab, and then talking about the results. I would say that it is very common. Not for a demonstration, but even then you still follow that structure, it's still there. I can't think of any time I wouldn't use that. It's a structure that breaks it down in neat divisions.

The findings in this study that the three phases of pre-lab, lab, and post-lab are essential aspects of laboratory activities is consistent with information provided in the reviewed literature (e.g. Tamir, 1977; Tamir and Lunetta, 1978; Lunetta and Tamir, 1981; Nadeau, 1984; and Nay, 1986).

Level of Inquiry

Students in junior high school are seen as requiring considerable structuring and guidance in performing their laboratory investigations. However, with an increase in grade level more of the structuring is removed.

Table 3 shows that 5 of the 8 observed investigations had fair level student inquiry (e.g. 21-40% student initiation of the scientific process skills). Similarly, analysis of the observed investigations and laboratory reports for use of the scientific process skills, as shown in Appendix I (Tables 19-26), reveals that some scientific processes are used primarily by teachers and/or laboratory manuals and only minimally by students.

The process skills most commonly initiated or discussed by teacher and/or laboratory manual were:

1. Identifying and formulating the problem.
2. Identifying variables.
3. Seeking background information.
4. Developing experimental steps.
5. Listing materials required.
6. Outlining safety precautions.
7. Providing methods for recording of data (e.g. charts).
8. Providing for application of discovered knowledge.

The process skills most commonly outlined as student initiated were:

1. Hypothesizing.
2. Collecting and setting up apparatus.
3. Performing the experiment.
4. Recording data.
5. Making guided inferences (e.g. with assistance of laboratory manual).
6. Treating data mathematically (e.g. calculating, with assistance of teacher and laboratory manual).

Researcher field notes also indicate that in grade 7 investigations, teacher and/or manual structuring is extensive for the three phases of laboratory activity (Appendix G, Tables 11-13). In grade 9, although the first two investigations show considerable teacher/manual structuring, the third investigation is open-ended with minimal teacher/manual structuring (Appendix G, Tables 15-18).

Teacher interviews indicated that Mr. Scheele, the grade 7 teacher, felt that laboratory investigations were frequently verification of a concept (low level inquiry), whereas for Mr. Priestley, the grade 9 teacher, this was not the case (Table 6, statement 11, p. 128). This is further illustrated by the interview statements from each of these teachers.

Jeske: Do most laboratory experiments teach students something new, or are they simply verifications, where the students often know the answers before they perform the experiment?

Scheele: It is unfortunate, but we are trying to hit the mass majority and you can't go open-ended because you would lose 80% of the kids. You can't just give them notes so you try to get these labs as verification and you call them experiments, but are they really experimenting, are they unsure of the results, probably not. They are a verification, except at times when you branch off, like these projects I was mentioning before for the science fair.

Jeske: Frequently, it is said that laboratory experiments do not teach students anything new. They know the answers before they perform the experiments and the lab work only becomes a verification. How do you see this?

Priestley: I would hope not. I kind of look at lab work as investigating and not proving, and often I would not after posing a problem give a possible answer until the investigation is over and then what are your conclusions, and what does that do to disprove or prove your hypothesis. So I don't think the accusation is fair that it is proving or disproving what the teacher said. I would hope that when we summarize the results from the six different groups that the conclusions would sort of be logically drawn out that this does support the idea. Many times the kids are amazed at what happens.

A rationale for the more extensive teacher/manual structuring at the grade 7 level, than at the grade 8 and 9 level, is provided by Mr. Scheele.

Jeske: What I gather from the students is that many of them did not do experiments in elementary school.

Scheele: No, they haven't, that is the problem with grade 7, you have to take it fairly slow. Right at the start of the year we spent a week just on lab safety rules and how to light bunsen burners, but they forget. Sometimes, you have to forget about the content when you are doing labs, this is one thing that kind of bothers me, and you have to spend more time on lab safety rules, manipulation and stuff like that.

Jeske: It must be pretty hard for them when they have to handle equipment which they have never seen before.

Scheele: That's right, what we take for granted they have never used before, and maybe never seen. You ask them to get a stirring rod or something to stir with and they have no idea what you are talking about.

Additional evidence for extensive structuring of investigations at the junior high level is inferred from the teachers agreeing that open-ended investigations (e.g. high level inquiry) could not be used effectively on a daily basis (Table 6, statement 7, p. 127). This is illustrated by Mr. Priestley's interview statements.

Jeske: Do you feel that unstructured laboratory investigations can be used at the junior high school level on a daily basis?

Priestley: I don't think so with the students I have, I think they need quite a bit of structure before they can work into that. They just don't have the prior knowledge, they don't have the background they can draw on just to have sort of open-ended questions. That's my feeling either right or wrong.

Table 8, statement 3, (p. 137) indicates that 7 of the 9 students interviewed show a preference for structured (i.e. low level inquiry) investigations. Table 4, statement 27, (p. 116) substantiates this by indicating that 30% or less of the students at each grade level agree that laboratory investigations should not have so many instructions in order to allow students to think more about how to do the experiments. It is of particular interest to note that the lowest percentage of agreement is at the grade 9 level. An interview excerpt is cited to exemplify student preference for structured investigations.

Jeske: Would you like to, or prefer to work on experiments that you devised or invented yourself instead of the ones you have been working on?

Karl: I think I would rather do experiments that somebody else has already laid out. It is interesting sometimes where you have to maybe make your own experiments where you can prove a point, but it is fairly difficult and it is better to stick to what someone else has devised.

The literature review tends to encourage high level inquiry. Lunetta and Tamir (1979) stated that "generally over the past two decades, science teachers have moved away from laboratory activities in which students merely illustrate, demonstrate, or verify known concepts or laws." Nagalski (1980) wrote "through inquiry students are conditioned to think critically and creatively, and to generate their own conclusions." Nadeau (1984) in studying a high school setting found that "students can become independent inquirers in a laboratory program." Okebukola (1985) concluded from his study that students acquire the inquiry process skills best while engaged in hands-on laboratory activities. In the present study, however, most of students preferred teacher and/or laboratory manual structured investigations (e.g. fair to moderate student levels of inquiry). Perhaps, students lack of extensive involvement with open-ended investigations has a bearing on their preference.

Assembling of Equipment and Preparing of Materials

From, the data it can be inferred that assembling of equipment and preparation of materials can be left to students during laboratory investigations.

Table 6, statement 17, (p. 128) shows that the three teachers interviewed agree that in their classes students assemble as much of the needed apparatus as possible. This is illustrated by Mr. Priestley's interview statements.

Jeske: What about in organizing laboratory activities, what techniques do you use that seem to work well at the junior high school level?

Priestley: Well, some of the equipment I set up myself at the stations, but I rather put it out and let them construct it themselves. For example, in the distillation experiment which we did I put the rubber stoppers, test tubes and a straight piece of glass on the tables and they would have to bend the glass into a right angle. So I leave as much of the manipulation and assembling of the equipment to them as possible. I also don't measure out the chemicals, if it calls for 25 grams of a chemical, I don't measure that out for them. I tell them they have to do it, and I leave the supplies either at the front or on a trolley and they get it themselves. So I really tend to leave as much of the manipulation and building of equipment to them as possible.

Jeske: So it becomes a learning experience?

Priestley: Yeah.

Taped pre-laboratory discussions also reveal that students in each laboratory group have the responsibility of assembling the equipment as needed for an investigation. An example is provided by an excerpt from the pre-laboratory discussion for Investigation Two in grade 7 (Appendix O).

Intern Teacher: You are responsible for setting up the bunsen burner, setting up the stand and boiling the water. The iron rings are on the counter and the asbestos pads for heating your water are in the first drawer. Start your bunsen

> burner, I will get your leaves, the beakers are in the cupboard.

From Table 8, statement 19, (p. 139) it can be seen that all of the students who responded liked to be involved in assembling and constructing needed laboratory equipment. A grade 7 student's statement is cited as an illustration.

Jeske: Would you like to construct in the laboratory some of the simple machines and apparatus that you use to carry out experiments?

Jacob: Oh yeah, I would like to.

Jeske: What would you get out of constructing your own equipment?

Jacob: It would help you to know how it worked and things like that, you would get a better idea of what you are doing and how the thing you are using works.

Most laboratory equipment assembling, according to the present study, can be left to students at the junior high school level.

Preparation of Lab Reports

The data reveal that laboratory reports are a viable alternative to structured student laboratory notes.

In Table 6, statement 13, (p. 128) it is seen that the three teachers interviewed agree that it is desirable to have students engaged in writing some laboratory reports. The emphasis that was placed on students having to prepare laboratory reports appeared to vary from teacher to teacher. The use of laboratory reports as an alternative to provided inference questions is indicated by Mrs. Dalton.

Jeske: Do you use lab reports most of the time?

Dalton: Yeah, not as much in grade 7, they are just starting with lab reports in grade 7, because it has taken me this long to get them going [interview March 11]. But, by grade 9 they are used a lot. In grade 7 they still have to prepare their charts and graphs and so on. No, they don't very often just fill in the blanks to questions that are asked.

Jeske: So that part of the C.R.I.B., the inference questions, you just kind of chop off?

Dalton: Yeah.

From researcher field notes (Appendix G, Tables 11-18) and from an inspection of the observed investigations (Appendix H) in conjunction with student laboratory reports (Appendix J) and researcher comments in the analysis for scientific process skills (Appendix I, Tables 19-26), it can be seen that students were required to prepare laboratory reports for 2 of the 8 observed investigations. This indicates that laboratory reports were used sometimes to replace the structured student laboratory notes. Laboratory reports required students to initiate some of the scientific process skills previously initiated by the teacher and/or laboratory manual in structured student notes. Students were required to initiate process skills such as: hypothesizing, listing variables, outlining safety precautions, designing methods of recording data, ordering of data, and making of inferences. Two entries from researcher field notes are provided as illustrations. The first entry refers to Investigation One in the grade 8 class.

> Students to prepare a lab report. The teacher explains what students are to do in writing the lab report. Students are given 30 minutes of class time to prepare the pre-laboratory sections of their lab reports (e.g. problem-statement, hypothesis, variable identification, chart preparation for recording of observations, etc.).

The second entry quotes the teacher for Investigation Three of grade 9.

> "The last investigation in this series is not written up, you have to write it up using all the processes."

Table 8, statement 5, (p. 137) indicates that 8 of the 9 students interviewed would rather do laboratory reports than questions at the end of experiments. The following are some of the advantages students related for preference of laboratory reports.

1. Requires you to recall everything that happened during the investigation.
2. More fun to do the work by yourself instead of having it laid out for you.
3. Involves more personal involvement in the investigation, it is more of you as an individual.

Two excerpts from student interviews indicate a preference for writing of laboratory reports:

Jeske: Do you like doing lab reports better than answering the series of questions at the end of an experiment?

Karl: Well, everybody would probably say they enjoyed the questions better, there is less of them and they are not as hard. But as far as the learning goes it is better to do the lab reports. The report is fully detailed and going over all the steps over and over and sort of permanently impressing the scientific processes on your brain.

Jeske: In some experiments you have a series of questions-inference questions, application questions and so on. Do you like doing these types of questions better than having to write lab reports.

Rachel: No.

Jeske: Why not?

Rachel: Because lab reports are easier because it comes from you, like you write down what you think. You write down what you know, and in the questions you don't understand it all. It is easier when you do lab reports because you know everything you are writing.

Jeske: What about studying for exams, would it be just as easy to study from laboratory reports as from a series of questions?

Rachel: I think so, much easier probably.

The literature review does not explicitly cite students as having a preference for writing laboratory reports over doing questions in laboratory exercises. However, it would seem that preparing of laboratory reports would allow students to more extensively express the employment of laboratory skills as outlined by Blosser (1988) (e.g. acquisition skills, organizational skills, creative skills, and communicative skills). The evidence cited in the present study supports the inference that student prepared lab reports can replace structured student laboratory notes.

Student-Student Interaction During Laboratory Activities

It can be inferred from the data that learning is facilitated by students helping each other during laboratory activities.

Two statements in Table 4 are supportive of this inference. Statement 22 (p. 116) indicates that the majority of students at each grade level feel that most students discuss their data and findings within their laboratory groups. Likewise, statement 25, (p. 116) shows that the majority of students at each grade level agreed that lab partners often assisted them in getting a better understanding of experiments and their interpretations.

The SLIC observations summarized in Table 10 indicate that each of the 9 students observed spent some laboratory time in either offering explanations, answering questions, giving directions, asking questions, or listening to someone else do so (e.g. SLIC categories of transmitting information, asking questions, and listening). The grade 7, 8, and 9 selected students spent an average of 10%, 11%, and 18% of the observed laboratory time respectively, in activities associated with transmitting information, asking questions, and listening. Although some of this time was spent in interacting with the teacher, the majority of it involved student-student interactions.

Table 7, statement 6, (p. 134) shows teachers interviewed agree that during laboratory activities students improve their organizational skills and learn to work with others. This is illustrated in an interview with Mr. Priestley regarding the open-ended investigation performed by grade 9 students, e.g. Investigation Three.

Jeske: What about within the lab as they were working, did they say how do I do this?

Priestley: They often said how do we separate this, and I said just go back and look at the different techniques we have learned.

Jeske: So you didn't give them much help at all?

Priestley: No, I was really obstinate and miserable, I didn't really give them any help.

Jeske: Which is probably a real good experience.

Priestley: Yeah, they really didn't need it, because between the members within each group, they had sufficient expertise to come up with an answer.

Table 8, statement 14, (p. 139) indicates all 9 students interviewed agree laboratory partners assist each other in understanding an experiment. Two interview excerpts are provided as evidence.

Jeske: Did you require help from the teacher while performing the experiment? In other words, did you put up your hand, or was the teacher at your table to give you some information, or did you do the whole experiment on your own?

Elaine: We worked it out within the group, so that helped to explain things.

Jeske: So you got your information from within the group and not from the teacher?

Elaine: Right.

Jeske: Would you tend to learn more if you had to do all the work by yourself without lab partners?

Karl: I don't think so actually because if you did it by yourself, and I know myself I have been corrected for making some mistakes with the scientific processes that would have been fatal errors in my reports. Working with a group like that really helped me to change those ways and get to do it properly.

In the literature reviewed Johnson (1981) proposed that peer relationships influence educational aspirations and achievement. Abraham (1976) related the importance of verbal interaction between students during scientific inquiry by concluding that "homogeneous grouping is an effective way of encouraging greater amounts of valuable verbal instruction." Both of these literature citings are supportive of the present inference that learning is facilitated by students helping each other during laboratory activities.

Student-Teacher Interaction During Laboratory Activities

Student-Teacher Interaction At The Individual Group Level

The data reveal that student-teacher interaction at the individual group level is considered important.

Table 4, statement 29, (p. 116) shows most students do not feel that teachers are providing them with too much help during laboratory activities. Similarly, all of the students who provided an interview response indicated they like the teacher to come to their laboratory table while doing experiments. Three student interview excerpts are cited for illustrative purposes:

Jeske: Do you like the teacher to come around and visit at your lab table?

Rachel: Yeah.

Jeske: Why?

Rachel: Because if I am doing something wrong I want to know. I don't just want to go, oh that's O.K. I want to know and want to correct it.

Jeske: Should the teacher come around a couple of times while you are doing lab work?

Jacob: Yeah, just to watch.

Jeske: And, maybe ask you a couple of questions?

Jacob: He should watch you and ask you how you are doing, what's wrong, or what's going on, or something like that. But, I don't think he should help you because then we won't learn anything.

Jeske: So in other words you learn by doing?

Jacob: Yeah, by doing and not by getting help.

Jeske: If during the laboratory work the teacher comes around even if you don't need any help, just comes around to visit and to talk, would you like that?

Alfred: Yeah, because that will help you in a way because you might think you know what you are doing, but you really don't. So when you are asked how it is going you can reflect on how it is.

Researcher field notes (Appendix G, Tables 11-18) and taped pre-laboratory discussions (Appendix O) indicate that teachers operated at the individual group level during the laboratory work phase. This is shown in the following notations.

Researcher Field Notes: (Aston Junior High)	During lab work teacher circulated around the room assisting students as necessary.
Pre-Lab Discussion: (Chadwick Junior High)	(1) Attach the copper wire to the lever under the pan of your balance. I will have to come around and show you, there is a little sort of lever under the pan, and I will have to show you that. What you do is connect the copper wire around there. (2) Any questions so far? I'll be around to help you.

Teacher interview statements also indicate that teachers operate at the individual group level rather than the whole class level while students are performing their experiments. Two interview excerpts are provided as examples.

Jeske: Students are saying, I want the teacher to have an interest in me and what I am doing. They want to socialize more.

Scheele: Yeah, I try to do that, I try to go around to every kid even if they are not having problems just to see how it is going. There is again the old student-teacher ratio showing up, and I don't know how you would solve that. Because during lab work you are going around, you are watching and commenting on things.

Jeske: Students are saying that they would like the teacher to come around and visit more, to see how it is going, and to tell them whether they are doing the experiment correctly. They are saying, the teacher should come around and show more interest in me as a person.

Priestley: Yeah, I do move around, and move around all the time. But, I guess they feel the amount of time I spend with any one group, or with an individual within that group, is very minimal. But again just numbers if you have 25 students and 40 minutes, a visiting of a minute and a half with each one is a maximum and some will require more help than others. Maybe you tend to leave the ones who are doing well on their own and help the ones who are bogging down. So it could be a very justified complaint.

The research literature examined appears to be in disagreement on the desirable extent of student-teacher interaction during laboratory activities. Shymansky (1976) studied the relationship between the length of student-teacher interaction and student behavior. It was found that lengthy one-to-one interactions may distract students resulting in reduced work and learning. Likewise Shymansky and Penick (1982) show, from the results of five studies conducted in K to 8 settings, that students seem to stay on-task better during hands on activities if the teacher interacts less with them. Beasley (1983) also observed that higher task involvement occurs during laboratory activities where the teacher operated at the whole class level rather than the individual group level. Although Darlington (1986) and Tobin (1986) do not appear to directly suggest more student-teacher socializing they do, however, definitely indicate that teachers should move from group to group during laboratory activities instead of operating at the whole class level. Both teachers and students in the current study showed a preference for teacher-student interactions at the individual group level.

Dealing With Alternative Conceptions

The data show that laboratory activities provide conditions required to reveal and address student alternative conceptions.

The post-laboratory discussion of Investigation One in grade 9, as cited in Chapter 4 and repeated presently for ease of discussion, illustrates the opportunity provided for dealing with student alternative conceptions.

Priestley: Question Number 2, "Do copper chloride and sodium chloride give the same color flame? If not which element produces the color"?

Priestley: Copper chloride, there are two kinds of atoms in copper chloride, copper and what else?

Student One: Chloride.

Priestley: Chlorine. In sodium chloride there are two kinds of atoms, sodium and chlorine. Alright the copper burns green and sodium burns yellow. Now they are asking you whether this or this is giving you the color (pointing to copper chloride on chalkboard).

Student One: Copper.

Priestley: That would be the copper, why the copper?

Student One: When we burned the copper it showed a green color.

Priestley: What is the chlorine doing to the color?

Student One: The color of chlorine in copper and chlorine would be the same as in sodium and chlorine.

Priestley: If chlorine is giving the color then it will be the same color in copper chloride as in sodium chloride. Chlorine wasn't giving the color. So the copper and the sodium are giving the color because chlorine is common to both compounds, so its color should be common.

Student Two: Why can't it be a combination of both? A combination of the color of copper and the color of the chlorine.

Priestley: Well, if you want to prove that you could try copper oxide and copper something else in the flame test.

Student Two: But, that doesn't prove which one it would be.

Priestley: Well, listen if you take copper sulfate, copper oxide, and copper chloride and burn them all, and you get green, green, and green then it would indicate that this must be due to the copper.

Student Two: The copper and the chlorine are chemically combined so the copper as well as the chlorine should give the color...

Priestley: I am sure the chlorine is having some effect. With the naked eye you wouldn't see that, only if you were using a spectroscope, where you analyze the spectrum would you notice that.

Supposedly, Student Two heard Mr. Priestley's discussion of the provided background information to Investigation One (e.g. reading and explanation of background information as cited in Appendix C). This student had performed Investigation One and made the required observations. In addition, Student Two listened to the post-laboratory discussion for question two between Mr. Priestley and Student One. Nevertheless, Student Two maintained that the color of the flame resulted from the combination of both elements composing the compound.

According to everyday experiences the combining of two or more colored miscible materials results in a substance having the combined color of the mixed materials (e.g. combining different colors of paint). Consequently, Student Two had a basis for being persistent. When the emission spectrum of a compound is studied with a spectrometer of great resolving power it is found to have a band spectrum resulting from the elements composing the compound. However, Student Two did not have such a spectrometer and was required to base inferences on observations made with the unaided eye. The persistence of Student Two in maintaining that the flame color results from both elements composing the compound is consistent with Hashweh (1988) indicating that "preconceptions seem to be resistant to change." It is indicated that students' preconceptions can often be very reasonable, and therefore could be used as pedagogical devices (e.g. could be used to make teachers aware of the existence of student preconceptions). Provision of this awareness is supported by Hashweh (1986) stating that often "teachers are unaware of student preconceptions".

In the discussion Mr. Priestley attempted to convince Student Two to base the inference for question two on the observations made during the investigation. This coincides with Hashweh (1986) who stated that the task of the science educator is to "get the student who uses a certain alternative conception to interpret certain phenomena, to use the scientifically accepted conception in interpreting that particular phenomenon." It is shown in the current study that students have alternative conceptions, and that laboratory activities provide ideal circumstances for addressing them.

Student-Experiment Interaction During Laboratory Activities

Student Engagement in Laboratory Activities

From the data it can be inferred that provision of laboratory activity does not result in active engagement of all students.

Table 4, statement 21, (p. 116) supports this inference by indicating that less than half of the grade 7 students and approximately three-quarters of grade 8 and 9 students who responded to the science opinionnaire saw themselves as getting actively involved in performing laboratory experiments.

Researcher field notes relate incidents which portray a lack of, or partial, engagement of individual students in the provided laboratory activities. Two examples are cited.

Researcher Field Notes: Student got kicked out at beginning
(Chadwick Junior High) of the lab portion of the class for
unacceptable behavior (being
extremely noisy and fooling
around).
Student was sent to the office.

Researcher Field Notes: Pre-laboratory discussion
(Arfvedson Junior High) (discussion of background
information to Investigation Two).
Student moved at beginning of
period because he was talking and
aggravating some of the girls
next to him.

The perceived partial engagement of students is also supported by SLIC checklist observations. From Table 10 it can be seen that an average of 8% of the observed laboratory phase time was spent in passive observation. Table 10 also shows that an average of 14% of the observed laboratory phase time was given to non-lesson related behavior.

The literature examined supports the inference that provision of laboratory activities does not result in active engagement of all students. Tobin (1984) found that grade 6, 7, and 8 students in Australia spent 37% of the total time allocated to laboratory activities (pre-laboratory, laboratory, and post-laboratory) in off-task behavior. Tobin also reported that 30% of the time allocated to collecting of data (during the hands-on laboratory phase) was given to off-task behavior. The current study also revealed that students spent 14% of the time allotted to collecting of data in off-task behavior.

Operation of Learning Cycle in Laboratory Activities

The learning cycle is not fully operative in the observed investigations.

The first phase of the learning cycle, i.e. exploration, did not materialize in the observed investigations. According to Renner, Abraham and Birnie (1985) the investigations used must meet certain criteria (e.g. students should not be informed of the concept before the investigation is begun, nor should the student be able to discern the concept by reading the background information or experimental steps). In the investigations observed it is possible for students to determine the concept, etc. to be learned by reading the provided background information or experimental design. Two examples are provided as evidence. Investigation Two for grade 9 provides the problem statement of, "How may one distinguish between a mixture and a compound (pure substance)"? In the provided background information the following statements are made.

> If the original materials can be separated by physical processes (mechanical means), such as, dissolving (solubility) or magnetic attraction the product is not a compound. If the product cannot be physically separated in to its original components, and if it retains a new set of properties it is probably a compound.

For Investigation One, grade 7, the problem statement is, "What is one kind of food produced by green plants"? In question 4, which is incorporated into the procedure for the investigation, the following statement is provided.

> Glucose is the simple sugar produced in green plants by photosynthesis.

Phase two of the learning cycle (conceptual invention) is operative to some extent in the observed investigations, in that students discuss their finding within their laboratory groups (e.g. Table 4, statement 22, p. 116). However, the class findings are not discussed until students have written their laboratory reports or have answered the provided inference questions. It would seem that for the learning cycle to be fully operative a greater emphasis on class discussion after the exploration phase would be required.

The third phase of the learning cycle, conceptual expansion, appears to be adequately provided for in the observed investigations. Evidence for this is indicated by the provided investigations allowing the students to practice the concept, principle, or generalization by providing inference questions, new problems, mathematical calculations, etc. (See Appendix H). In addition, some of the investigations are connected so that the concepts learned in one investigation can be applied in the next investigation (e.g. Investigation One and Two, in grade 8).

For the learning cycle to be fully operative the observed investigations need to be reorganized to allow criteria for the first and second phases to be met. According to Renner, Abraham and Birnie (1988) the learning cycle is "also a curriculum organization principle."

Impacts of Lab Activities From Teacher-Student Perspectives

Increasing Student Understanding

Laboratory activities assist students to obtain an increased understanding of scientific concepts.

From Table 4, statement 19, (p. 118) it can be seen that 78% of the students participating in the study indicated that they learned a lot from doing science experiments. This is supported by 14 students responding to question 30 of the opinionnaire by stating that laboratory work helped them to understand scientific ideas better (Table 5). Two student statements are retrieved from Appendix K as illustrations.

Student 16, Grade 8: I think science laboratory work is helpful because we can see what happens so we can understand the problem and why and how it happens, it helps to identify the terms and concepts better.

Student 15, Grade 9: I think science laboratory work is fun and useful. It helps people to understand more, because they are actually seeing what is happening. It also gives an explanation to what ever the question was.

Table 9, statement 8, (p. 147) shows that 8 of the 9 students interviewed felt that lab work helps them to understand scientific concepts better. Two interview excerpts which are indicative of this are provided.

Jeske: Could you learn about the scientific concepts as well without doing any lab work?

Alfred: No, I don't think so.

Jeske: Why not?

Alfred: Well you don't sort of understand, I don't understand it completely without doing the lab.

Jeske: So the lab work helps because it lets you see.

Alfred: Yeah, actually see what it is like sort of thing.

Jeske: Could you learn about the scientific concepts or ideas as well without doing any lab work?

Karl: You could probably learn them, not as well, but you would learn them. But, it is almost like an on the job training sort of thing, where if you actually have your hands on the thing, you are actually doing it, you remember it better, and it makes you even more willing, more open-minded to learn because it is not boring.

According to Table 7, statement 3, (p. 134) the teachers interviewed found that laboratory activities help students understand concepts by reducing the abstract to the concrete experience. An interview statement is provided to exemplify this.

Jeske: When looking at the cross section of a leaf there are a number of names of cells that students need to become acquainted with, how does the lab work assist them to do this?

Scheele: I think any time you see something, if you hear of, see it on a diagram, but then actually find it, see it for yourself, that really reinforces it. And these aren't fictitious things anymore. Here is a leaf and I can see these things.

The usefulness of reducing the abstract to concrete experiences to increase student understanding is supported in the research literature by Gagne (1970), Inhelder and Piaget (1958), and Hincksman (1973). According to Hincksman "the laboratory is essential for teaching children who are at Piaget's concrete operational stage, that is usually upper primary and junior secondary pupils."

This age range is particularly applicable to the junior high school students within the present study.

Motivating Students

Students are motivated to learn through involvement in laboratory activities.

According to Table 4, statement 8, (p. 117) over 80% of the students answering the opinionnaire enjoyed doing science experiments. Presumably that which students enjoy doing makes learning easier for them. As indicated in Table 5, eleven students also responded to question 30 of the opinionnaire by saying laboratory activities are interesting and fun. Two student responses are retrieved from Appendix K as examples.

Student 2, Grade 9: I think science laboratory work is a lot of fun, very educational and gets you thinking and wanting to do more.

Student 7, Grade 7: I think science laboratory work is very important. It teaches you to think out problems and to use your head. It is very fun and exciting because you learn and see things you never heard of.

Table 7, statement 2, (p. 134) shows that the teachers interviewed see laboratory work as helping to motivate students. Excerpts from two interviews are cited as evidence.

Jeske: What area of objectives would be best fulfilled through lab work?

Scheele: ... I still think motivational objectives, because the motivational aspect is there, and that's why we use lab work a lot...

Jeske: Why do you like to have your students involved in laboratory work?

Priestley: ...Plus I think it is a great motivational factor...

From Table 9, statement 1, (p. 146) it is shown that all of the students interviewed agreed that doing experiments encourages them to want to find out. This motivational aspect is illustrated in the following interview excerpts.

Jeske: Did the experiment encourage you to think about, or want to find the answer to the problem.

Elaine: Yeah.

Jeske: How did it do that?

Elaine: Because I didn't know what was happening in the first place, so I wanted to find out.

Jeske: When you think about laboratory work how does it make you feel?

Karl: You feel sort of curious, interested, you want to find out some new things. What certain things mean.

Jeske: Did Investigation One make you feel this way?

Karl: Yeah, because I wanted to find out. Whenever I get a problem put forth, it is kind of nice to be able to answer it you know. So it was a good experiment, you find something out.

In the research literature the motivational impact of laboratory activity is given recognition by Kempa and Dynan (1977), The Educational Policies Commission (1966), Denny and Chennell (1986), and Bryant and Marek (1987). Within the current study laboratory activities are also revealed as motivating students to learn.

Teaches Students How to Work With Each Other

Through involvement in laboratory activities students develop the social skills needed to work with others.

Table 4, statement 24, (p. 118) reveals that 76% of the students participating in the study enjoyed working with their lab partners. Supposedly enjoyment in working with partners indicates that those students have learned to get along with each other. This is supported by 66% of the students in the study indicating that they discuss their laboratory data and findings within their laboratory groups (Table 4, statement 22, p. 116). Additional support is provided by 72% of the students participating in the study indicating that working with lab partners helped them to understand the experiment better (Table 4, statement 25, p. 116).

According to Table 7, statement 6, (p. 134) the teachers interviewed agree that students develop social skills by engaging in laboratory activities. The following interview excerpts are provided as examples.

Jeske: What area of objectives would be best fulfilled through lab work?

Scheele: ...School is also a socializing process and if you are working in a group, which you have to do for lab work, then you have to assign tasks to the group members. I'll do this, you do that, and obviously that is also a problem, but it can be a benefit too.

Jeske: What types of teaching objectives or goals are most effectively fulfilled by doing lab work?

Dalton: Well, I think that it helps to get concepts across, but I think it also teaches them

> organizational skills, it teaches even some social skills in terms of learning to work with others. So it hits on a variety, really a broad spectrum of skills.

Two student interview statements are provided which indicate that students can learn to work with each other effectively.

Jeske: Do you help each other quite a bit?

Irene: Yeah, like last lab we were doing, she weighed the things out and I filled the beaker with water and stuff. So you are trying to help the other one, and so this way we can help each other without being totally brushed off.

Jeske: Do you ever get into little fights or disagreements?

Irene: No not really.

Jeske: You always work it out without getting into a hassle?

Irene: Yeah, we are not best friends, but we are not bad friends, we just get along good.

Jeske: So for your particular lab partners, why do you like working with them, what's so special about them?

Karl: I think it is mostly their cooperation, you feel good to be part of the team that's doing things right. And even when you do things wrong the others correct you properly.

In the literature reviewed recognition is given to the importance of students learning to work together during laboratory activities by Hurd and Rowe (1966), Tobin (1986), Kempa and Dynan (1977), and Thompson (1976). It is indicated in the present study that laboratory activities provide students with the opportunity of learning how to work with each other.

Affects Students' Attitude Toward Science

As students gain more experience with laboratory activities through active participation or increased years of involvement, their attitude toward science and laboratory activity appears to become more positive.

Three statements from Table 4 seem to be supportive of this inference. Statement 8 (p. 117) shows that grade 9 students enjoy doing science experiments more than grade 7 and 8 students (e.g. grade 7 against grade 9 gives a chi-square = 2.39, df = 1, p = 0.12). Statement 13 (p. 117) indicates that considerably fewer grade 9 than grade 7 and 8 students agreed that they did not want to take more science classes than they had to take (e.g. grade 7 versus grade 9, chi-square = 3.53, df = 1, p = 0.060). Statement 1 (p. 117) reveals that considerably fewer grade 9 students than grade 7 and 8 students find that reading science is difficult (e.g. grade 7 compared to grade 9, chi-square = 3.53, df = 1, p = 0.060). Perhaps reading science in grade 7, 8, and 9 is of equal difficulty, but an increased interest and a more positive attitude may make it seem easier.

The relationship between students' attitude toward science and experience with laboratory activities is exemplified by the following student interview excerpts.

The first interview statement is made by Nicolas, a grade 9 student with a positive attitude toward science and laboratory activity (opinionnaire score of 117). Nicolas was an active participant in laboratory activity (40% of laboratory time spent in manipulating apparatus and observing, See Table 10).

Jeske: Statement 16 of the opinionnaire said "science is dull for most people" and you responded with "agree". Could you give me your thinking behind this answer?

Nicolas: Like my friends, they think it's dull, they fall asleep in class, when they go to high school they won't even take any more science classes or anything.

Jeske: If you had to make it more interesting for them, what would you do?

Nicolas: I would get them more involved. Instead of doing worksheets and stuff like that, I would get them doing experiments.

The second interview statement is made by Karl a grade 7 student. Karl had a very positive attitude toward science and laboratory activity (opinionnaire score of 122) and was an active participant in laboratory activity (54% of laboratory time spent manipulating apparatus and making observations, See Table 10).

Jeske: Statement 16 of the opinionnaire said "science is dull for most people" and you responded with strongly disagree. Could you tell me why you think most people enjoy science and don't find it dull?

Karl: Many people they may say it is dull when they are reading out of a book, but then anybody can get bored, after a while, by just reading out of a book. If you were to ask all the people how science was, and if some of them would of said it was dull if they were reading out of a book, if you go in when they were conducting an actual experiment and ask how science was, then you would probably find that they all enjoy science because they would be having fun doing experiments.

Further support is provided by Table 8, statement 18,

(p. 139) showing that all of the interviewed students in grade 9 stated that much of what they learned in science and laboratory activities had applications to every day situations. Only one student out of three in grade 7 and 8 were in agreement that this was the case. The relationship between students realizing every day applications for what they learn in science class and their interest and attitude toward science and laboratory activities is illustrated by the following interview excerpts:

Jeske: Question 12 of the opinionnaire says "I think about things we learn in science class when I'm not in school" and you put down disagree. Could you tell me more about this?

Elaine (grade 9) (low attitude): Maybe some I do, but I think most of it is just related when we are in science class.

Jeske: Why might that be so?

Elaine: I don't usually talk about those things, you know, to friends, or something about science.

Jeske: Question 12 of the opinionnaire states "I think about thing we learn in science class when I'm not in school" and you said strongly agree. Could you tell me about this, and maybe give me an example of where you might use this?

Karl (grade 7) (high attitude): Often now that we are taking the cells you can, just when you are walking around, see plants and sometimes animals and bugs and stuff like this. And it's nice to know that these are things you learned about in school. You refer back to it and questions come to your mind, and you ask the teachers at school about them. And you think about it and you can ask about the plants what they are made of, and things like that.

When Rachel was asked about question 12 of the opinionnaire she replied as follows.

Rachel (grade 9) (intermediate attitude): I do think about

> a lot of things. My sister is studying to be a teacher and I always ask her questions about it. I always ask her about atoms and things like that.

Some support for laboratory activities influencing students' attitudes towards science is provided by the literature examined. McMillan and May (1979) in studying factors that influence attitude toward science for junior high school students concluded that laboratory activities do have an influence. McMillan and May stated that "despite the fact that previous research had been mixed with regard to the effect of curriculum, it was clear that pupils in this school preferred classroom formats which involved active involvement and experiences" (p. 220). The present study seems to indicate that this influence increases with an increase in students' experiences with laboratory activities.

Summary

The goal of the study was to examine what science laboratory activity actually is at the junior high school level, and to determine the learning outcomes attributed to it by participating students and teachers.

It shown that in the observed classrooms the three phases of pre-laboratory, laboratory, and post-laboratory were the hub for organizing of laboratory activities. Students were provided with laboratory investigations which had a considerable degree of teacher and/or manual structuring. However, as the grade level increased the amount of teacher and/or manual structuring decreased, with grade 9 students being provided with open-ended investigations (i.e. high level inquiry) as a culmination exercise to a unit of work. Assembling of equipment and preparation of needed materials was left to students, as much as possible. Most student interpretation of laboratory observations was guided by structured inference questions, but laboratory reports were used to some extent, and are seen as a viable alternative to inference questions by students and teachers.

Student-student interaction facilitated learning by laboratory group partners assisting each other in understanding of laboratory investigations. Teachers assisted students by circulating from one laboratory group to the other. That is, teachers interacted with students at the individual group level rather than the whole class level. Student-teacher interactions during post-laboratory phase discussions provided ideal circumstances as needed to reveal and address student alternative conceptions. Although students were given the opportunity to engage in laboratory activities, not all of the students experienced active involvement to the fullest extent. The student-experiment interaction within the teacher and/or manual structured investigations did not allow for the learning cycle to be fully operative.

Students and teachers feel that student involvement in laboratory activities increases student understanding of scientific concepts. Through engagement in laboratory activities learning is made interesting and fun and consequently seen by teachers and students as motivating students to learn more. Laboratory activities in requiring students to work in groups is considered by students and teachers as developing the social skills needed to work with others effectively. According to student responses it appears that students' attitudes toward science became more positive with an increase in experience with laboratory activities.

CHAPTER 6

SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

This chapter reviews the data collection and analysis methods, and summarizes the data collected on the basis of the research questions which guided the study. The implications for science educators are discussed with respect to the general findings of the study and literature reviewed. The findings of the study serve as a basis of recommendations for further research.

This study was an examination of what science laboratory activity actually was at the junior high school level, and the learning outcomes that were attributed to it by participating students and teachers. Three questions were used to guide the data collection and analysis.

1. How are laboratory activities organized at the junior high school level?
2. What is the extent of interactions between student-student, student-teacher, and student-experiment during laboratory activities?
3. Which learning outcomes do students and teachers attribute to involvement in laboratory activities?

Summary of Data Collection and Analysis

In the current study eight qualitative data gathering techniques were employed for a two to three week time period at each of the three junior high school grade levels (i.e. grade 7, 8, and 9), with each grade level being in a different school. A science opinionnaire was administered to students in each class, the data was categorized with respect to the "Nature" and "Impact" of laboratory activities. Numerical opinionnaire data were analyzed by using a computer statistical software package. From the opinionnaire responses the students indicating the most, intermediate, and least favorable attitude toward science and laboratory activities were selected for additional involvement in the study. This involvement included interviewing, observation with the Science Laboratory Interaction Categories (SLIC) checklist, and providing the researcher with prepared laboratory reports/notes. During class observations researcher field notes were recorded and the pre- and post-laboratory class discussions were tape recorded. Each teacher was interviewed from one to three times, depending on the teacher's schedule and the length of time the researcher spent at the school. Teachers were also requested to provide the researcher with copies of the observed laboratory investigations.

The observed laboratory investigations, along with the student laboratory reports/notes were analyzed for the level of student inquiry employed. Researcher field notes, transcribed interviews, and transcribed pre- and post-laboratory discussions were coded in the margins of the pages with key words or phrases to indicate what was said or happening. The coded field notes and transcriptions were then searched for recurring themes within the laboratory activity dimensions of organization, interaction dynamics, and impacts. Check marks on SLIC checklists for all observed investigations were tallied for each interaction category, and then converted to a percentage of observed laboratory time spent by each student in each of the interaction categories.

Summary of Research Findings

Organization of Laboratory Activities At The Junior High Level

The findings pertaining to the first research question, organization of laboratory activities at the junior high school level, are presented from the perspective of the teachers, students, and observer.

Structuring of laboratory activities. According to researcher observations a fair to moderate level of student inquiry was predominant in the observed investigations. This indicated that some of the scientific process skills (e.g. identifying and formulating a problem, seeking background information, and developing the experimental steps) are not used at all, or in some cases only sparingly, by students during their laboratory investigations. It also indicates that teacher and/or laboratory manual structuring of investigations is rather extensive.

The data collected showed that most students (80%), and all of the teachers, agreed that the current levels of teacher-directed student inquiry are adequate. Although students interviewed stated that having open-ended investigations once in a while was interesting and helpful, they preferred laboratory investigations which were structured by the teacher and/ or laboratory manual. All of the teachers indicated that high level inquiry probably could not be used effectively on a daily basis in their classes, since most students lacked the necessary background to operate at a high inquiry level.

Laboratory activities are composed of three phases. Teachers and the majority of students appear to understand laboratory activities as consisting of a pre-laboratory, laboratory and post-laboratory phase. The data showed that students found the pre- and post-laboratory phases useful in helping them to better understand the experiments being performed. According to teachers the three phases allowed the laboratory activities to be broken down into more manageable divisions.

Researcher observations indicated that the students' laboratory manuals have each investigation divided into process skills pertaining to the pre-laboratory, laboratory, and post-laboratory phases. Researcher observations also revealed that the pre-laboratory, laboratory, and post-laboratory phases were visible within activities provided in each of the classrooms.

Amount of laboratory work. Teachers within this study indicated that approximately half of their science courses consisted of laboratory activities. When students were asked about the amount of laboratory work being done in their classes about 90% agreed that the time was not excessive. All of the students interviewed indicated that they would prefer doing even more experiments and to spend less time in activities such as reading a textbook, and writing notes.

Although teachers were aware that the researcher was present to observe only laboratory activities, other instructional techniques were used during the researcher's presence, e.g. showing of films, lectures, and writing of notes.

Extent of student involvement. From the data collected it was seen that the teachers and all students interviewed agreed that assembling and constructing needed laboratory equipment should be left to students as much as possible. According to students, being involved in assembling equipment allows them to better understand its function and operation. The researcher observed students gathering needed equipment and materials from side counters and trolleys, and in assembling of retort stands, bunsen burner apparatus, equipment as needed for a "hot water bath", and preparation of microscope slides.

According to the data it appears that most students interviewed would rather prepare their own laboratory reports than answer the laboratory manual provided inference questions. Although students showed a preference for teacher and/or laboratory manual structured investigations, it appears that this structuring is not to include data interpretation. All of the teachers are in agreement that students should be involved, to some extent, in writing of their own laboratory reports. Researcher observations revealed that students were involved in writing student-structured laboratory reports for 2 of the 8 observed investigations. During the writing of laboratory reports students were engaged in activities such as listing variables, outlining safety precautions, hypothesizing, and developing methods of recording data.

Extent of Student Interactions During Laboratory Activities

The findings for the second research question, extent of student interactions during laboratory activities, are also presented, whenever possible, from the perspective of students, teachers, and observer.

Student-student interactions. The majority of students and all of the teachers agreed that during laboratory activities learning is facilitated by students learning to work together. According to researcher observations approximately 15% of the laboratory phase was spent by students assisting each other through verbal communication.

The data showed that approximately 25% of the students indicated that their laboratory partners sometimes got into arguments while performing laboratory activities. However, it was also indicated that students were usually capable of reaching an agreement between themselves. Teachers indicated that they generally moved students from one group to another whenever students could not work with each other as expected. However, it was also indicated that teachers seldom had to do this. The researcher did not observe any sign of disagreements between laboratory partners. However, there were indications that some groups tended to take longer to begin performing the experiments, perhaps suggesting that these students could not agree quickly on what to do, or how to do it.

Student-teacher interactions. Researcher observations showed that student-teacher interaction during the laboratory phase were usually at the individual group level. That is, teachers usually moved from group to group to observe and assist students as necessary. The data also revealed that teachers and student understood student-teacher interactions, during the laboratory phase, as occurring at the individual laboratory group level rather than the whole class level.

The majority of students (72%) indicated that teachers were not providing them with too much help during laboratory activities. However, it was shown that significantly more grade 7 than grade 9 students felt that teachers were providing them with too much help! All of the students interviewed stated that they wanted teachers to come to their laboratory stations to observe and to talk with them even if they did not require help. Although, teachers saw merit in socializing more with students, they found it difficult to put into practice because of relatively high student-teacher ratios. Researcher observations confirm that teachers usually did not spend more time with laboratory groups than was required in assisting them to perform the experiment.

It was shown from researcher observations that laboratory activities, particularly post-laboratory class discussions, provided ideal circumstances for revealing and addressing student alternative conceptions. It appeared that during the post-laboratory discussion teachers were provided with the opportunity to allow students to think about their observations and to challenge their alternative conceptions.

Student-experiment interaction. The data revealed that the majority of students (63%) saw themselves as getting actively involved in performing laboratory experiments. However, teachers concurred that doing laboratory experiments was more stressful, since it required more teacher management and supervision of students than other instructional techniques. Researcher observations indicated that students who are not actively involved in performing experiments tend to spend more time in activities such as getting supplies, passive observation, and non-lesson related behaviors. It was indicated that the non-lesson behaviors occupy approximately 14% of the time given to the laboratory phase (i.e. data collection).

Researcher observations indicated that the three phases of the learning cycle are functional to different extents within the observed investigations. The first phase (exploration) was shown to be essentially non-existent, the second phase (conceptual invention) was partially operative, and the third phase (conceptual expansion) was shown to be present in the post-laboratory phase.

Impacts Attributed to Laboratory Activities

The findings for the third research question, learning outcomes attributed to laboratory activities, are presented from the perspective of teachers and students only, as indicated in the research question. For purposes of presentation the learning outcomes revealed are classified as either cognitive, affective, psychomotor, or process.

Cognitive impacts. Most students (78%) indicated that they learn a lot from doing science experiments. Teachers and most of the students interviewed felt that laboratory experiments provided assistance in understanding of scientific concepts.

All of the teachers agreed that laboratory activities reduce abstract concepts to concrete experiences for students, allowing them to understand the scientific concepts better. All of the students interviewed showed concurrence by indicating that laboratory activities allowed them to see for themselves.

It is shown that a considerable number of students (55%) agreed that what they learn in science will be useful outside of school. This is further supported by more than half of the students interviewed indicating that what they learn by doing experiments often has application to every day situations.

Affective impacts. All of the teachers and students interviewed agreed that laboratory activities motivate students by fostering a desire to want to find out, a desire to want to learn more.

Participation in laboratory activities was seen by teachers as allowing students to develop the social skills needed to work with others. Most students (72%) concurred by indicating that working with their laboratory partners helped them to better understand experiments.

A good fraction of the students (60%) enjoyed going to science class, but many more students (87%) enjoyed doing laboratory experiments. Considerably more of the grade 9 students indicated that they enjoyed doing science experiments than grade 7 students (chi-square = 2.39, df = 1, p = 0.12).

Teacher interviews suggested that involving students in laboratory activities gives students a chance to see what they can do, gives a feeling of independence, i.e. gives students a chance to do something without having the teacher at the front of the class instructing.

Psychomotor impacts. From teacher and student interviews it was inferred that laboratory activities improve students' skills in handling and manipulating of laboratory equipment and materials.

Process impacts. All of the teachers and some students interviewed indicated that laboratory activities provided students with an opportunity to directly apply the scientific process skills (e.g. scientific process skills take on a reality for students).

Implications For Science Educators With Respect To Organization of Laboratory Activities

Although teachers involved in the current study provided laboratory activities for approximately 50% of the science course, at each of the grade levels, students would like to see an even greater emphasis on laboratory activities. Students not only enjoyed laboratory activities, (e.g. 60% enjoyed coming to science as compared to 87% enjoyed doing experiments), but both students and teachers portrayed laboratory activities as having numerous impacts upon student learning. It would seem feasible for science educators to place a considerable emphasis on laboratory activities within their science courses. Although the literature examined does not suggest a specific percentage of the course to be composed of laboratory activities, Ramsey and Howe (1969) Shulman and Tamir (1973), Renner (1972), and Hellingman (1982) indicated that the laboratory should be central to preparation of any science course.

Even though teachers and students preferred fair to moderate levels of inquiry, it appeared that most students would rather not have the post-laboratory write-up structured through provided inference questions. All of the students interviewed said they would rather prepare laboratory reports on their own. Teachers also felt that students should be involved, to some extent, in writing standard laboratory reports. It seems to be conceivable that teachers and curriculum developers could provide for more student preparation of laboratory reports at the junior high school level. Laboratory reports are frequently used in high school and in university level science courses to communicate student data collection and interpretation. Writing laboratory reports also allows students to practice their organizational skills, creative skills and communication skills, as outlined by Blosser (1988).

Both teachers and students showed satisfaction with fair to moderate levels of student inquiry, while the research literature appears to express a need for high level student inquiry (e.g. Lunetta and Tamir 1979, Nagalski 1980, and Hellingman 1982). Perhaps, teachers and curriculum developers need to give consideration as to how to bring these two perspectives closer together.

With Respect to Student Interactions During Laboratory Activities

Students in the current study expressed a desire for teachers to visit their laboratory groups for purposes of observing their work and showing an interest in them as individuals. Teachers indicated that they were doing this to some extent, but found it difficult to do since most of their time was given to supervision and to those students who were having difficulty in performing the experiments. This finding, however, seems to imply that teachers at the junior high level need to operate at the individual group level, rather than the whole class level, as much as possible. The literature examined was not clear on this point since some of the research suggests that teachers should operate at the individual group level (Darlington 1986, Tobin 1986), while other research suggests that teachers should operate at the whole class level (Shymansky 1976, Shymansky and Penick 1982, and Beasley 1983).

The literature reviewed with respect to the learning cycle reveals the importance of each phase of the learning cycle in the teaching of high school physics through laboratory activities (Renner, Abraham, and Birnie, 1988). According to these authors "thoroughly explaining a concept before providing experiences with materials results in little or no conceptual understanding" (p. 56). The findings of the present study indicated that the learning cycle was only operative to a very minimal extent within the observed investigations. This suggests that teachers and curriculum planners need to examine the feasibility of employing the learning cycle during laboratory activities in all science courses. However, in many cases this may necessitate a change from low level inquiry to high level student inquiry. According to Renner, Abraham, and Birnie (1985), "the active experimentation expressed in the learning cycle is not the verification laboratory so often encountered" (p.322).

With Respect To Learning Outcomes of Laboratory Activities

The learning outcomes attributed to laboratory activities by teachers and students within this study should be made only with reference to the specific laboratory learning situation described within the study (e.g. students working in laboratory groups, extensive teacher and/or manual structuring of most investigations, teacher-student interactions at the individual group level, etc.). It would seem that a different set of circumstances generates new learning outcomes. For instance, to the open-ended grade 9 investigation observed students attributed characteristics such as more challenging, gives us more of a chance to see what we can do, makes you think more, and is more exciting. This seems to imply that learning outcomes attributed to laboratory activities can only be understood with respect to a particular learning situation. This means that when the effectiveness of learning outcomes is examined, that it be done with respect to the learning situation to which the outcomes are attributed. The literature reviewed indirectly gives support to the need for understanding of learning outcomes in terms of specific learning situations by providing many different lists for learning outcomes, none of which can be thoroughly understood without reference to a description of a particular laboratory learning situation.

Recommendations For Further Research

1. The present study indicated that laboratory activities provide ideal circumstances for revealing and addressing student alternative conceptions. Further research needs to be conducted to determine the effectiveness of fair to moderate level student inquiry laboratory activities in altering students alternative conceptions as revealed at the junior high school level.
2. In the literature examined West (1978) and Welsh (1980) stated that there was no convincing evidence to support the value of laboratory instruction. The present study revealed predominant learning outcomes such as increasing student understanding, motivating students, teaching students how to work with others, and improving manipulative and observational skills. All of these learning outcomes are supported in the research literature (e.g. Thompson 1976, Denny and Chennel 1986, Bryant and Marek 1987, Lehman 1989). To give laboratory activities credibility further research is required to measure the effectiveness of the learning outcomes indicated. This research however, has to be done relative to learning

situations for which the learning outcomes have been ascribed.

3. Students in the present study indicated a need for increased teacher-student interaction at the laboratory group level. Some of the literature reviewed advocates teacher-student interaction at the individual group level (e.g. Darlington 1986, Tobin 1986), while others emphasize interaction at the whole class level (e.g. Shymansky and Penick 1982, Beasley 1983). Further research is needed to determine the positive and negative effects that different modes of teacher interactions with students, have on student laboratory active involvement.

4. According to Renner, Abraham and Birnie (1988) "the learning cycle is based upon the assumption that each of its phases is necessary" (p. 40). The present study indicated that the first phase of the learning cycle (i.e. exploration) was essentially non-existent in the observed investigations. Research needs to be conducted to determine how employment of the exploration phase would enhance the learning outcomes of junior high school laboratory activities.

5. The present study seems to indicate that students' attitude toward science and laboratory activities becomes more positive with an increase in students' experience with laboratory activities. Additional research needs to be conducted to determine whether

this finding can be generalized to other learning situations at the junior high school level.

6. According to the present study the three phases of pre-laboratory, laboratory, and post-laboratory are central to the teaching-learning in laboratory activities at the junior high school level. The current study also showed that laboratory activities, particularly the post-laboratory discussions, provided ideal circumstances for revealing and addressing students' alternative conceptions. This suggests that further research is required to examine the role of the pre-laboratory, laboratory, and post-laboratory phases in investigating and dealing with students' alternative conceptions at the junior high school level.
7. In the present study it was indicated that students showed a preference for laboratory investigations which were structured by the teacher and/or laboratory manual. It was also indicated that teachers felt that open-ended investigations (high level inquiry) could not be used on a regular basis in their classes. The literature reviewed suggests a need for employing high level inquiry (e.g. Lunetta and Tamir 1979, Nagalski 1980, and Hellingman 1982). Further research is needed to examine the feasibility of employing high level student inquiry in Alberta junior high schools.
8. The present study reveals that students and teachers

agree that performing laboratory activities assists students to obtain a better understanding of scientific concepts. Further research needs to be conducted to determine the extent of understanding that results from engagement in laboratory activities. In such a study the following questions need to be considered:

(a) What did students learn as a result of their laboratory experiences?

(b) How does student understanding of a concept as enhanced by laboratory activity compare to the extent of student understanding of the concept as obtained through other instructional modes?

9. In the present study the three weeks of observations at each school were scheduled one after the other. This presented difficulty in that some observed laboratory activities were incomplete at the end of the three week observation period. This was particularly evident in laboratory investigations in which students were required to write laboratory reports. The teachers needed time to mark the laboratory reports. This meant that the researcher was not present when these reports were returned to students. Consequently, the researcher missed the post-laboratory discussions for these laboratory investigations. It would seem advisable in future research of this nature to have at least a one week break between the scheduled observation periods to accommodate these kinds of unforeseen circumstances.

BIBLIOGRAPHY

Abraham, M.R. "The Effect of Grouping on Verbal Interaction During Science Inquiries." *Journal of Research in Science Teaching* 13,(2), 127-135, 1976.

Alberta Education. *Curriculum Guide for Junior High School Science.* Department of Education, Province of Alberta, 1978.

Atkin, J.M., Karplus, R. "Discovery or Investigation?" *The Science Teacher* 29(5), 37-40, 1962.

Ausubel, D.B., Novak, J.D. and Hanesian, H. *Educational Psychology A Cognitive View* (2nd ed.) Holt, Rinehart and Winston, Inc. New York, U.S.A., 1978.

Bates, G.C., "The Role of the Laboratory in Secondary School Science Programs." In *What Research Says to the Science Teacher* (Vol. 1) Washington, D.C., National Science Teachers Association, 1978.

Beasley, W. "Teacher Management Behaviors and Pupil Task Involvement During Small Group laboratory Activities." *Journal of Research in Science Teaching* 20(8), 713-719, 1983.

Beasley, W. "Improving Student Laboratory Performance: How Much Practice Makes Perfect?" *Science Education* 69(4), 567-576, 1985.

Bloom, B. "The New Direction In Educational Research: Alterable Variable." *Phi Delta Kappan,* 61(6), 382-385, 1980.

Blosser, P.E. "Labs- Are They Really As Valuable As Teachers Think They Are?" *The Science Teacher* 55 (5), 57-59, 1988.

Bogden, R.C. and Biklen, S.K. *Qualitative Research for Education: An Introduction to Theory and Methods.* Allyn and Bacon, Inc. Boston, Massachusetts, 1982.

Bryant, R.J., Marek, E.A., "They Like Lab-Centered Science" *The Science Teacher* 54(8), 42-45, 1987.

Bybee, R. "The Effectiveness of an Individualized Approach to a General Education Earth Science Laboratory." *Science Education* 54, 157-161, 1970.

Carter, J., and Associates *Life Science: A Problem Solving Approach.* Boston, Massachusetts: Ginn and Company, 1977.

Charen, G. "Laboratory Methods Build Attitudes." *Science Education.* 50(1), 54-57, 1966.

Darlington, C.L., "Great Labs!" *The Science Teacher* 53(2), 29-31, 1986.

Denny, M. Chennell, F. "Science Practicals: What Do Pupils Think?" *European Journal of Science Education* (3), 325-326, 1986.

Doran, R.L. "Assessing the Outcomes of Science Laboratory Activities." *Science Education* 62(3), 401-409, 1978.

Driver, R., Easley, J. "Pupils and Paradigms: A Review of Literature Related to Concept Development In Adolescent Science Students." *Studies In Science Education* 5, 61-84, 1978.

Edmonton Public Schools *Curriculum Resources Information Bank (C.R.I.B.)* Edmonton, Alberta: Edmonton Public School Board, 1974.

Educational Policies Commission *Education and the Spirit of Science.* National Education Association, Washington, D.C., 1966.

Fisher, T.H. "The Development of An Attitude Survey For Junior High Science" *School Science and Mathematics* 73(8), 647-652, 1973.

Fredette, N., Lochhead, J. "Student Conceptions of Simple Circuits." *The Physics Teacher* 18(3), 194-198, 1980.

Gagne, R.M. "The Learning Requirements for Inquiry." *Journal of Research in Science Teaching* 1(2), 144-153, 1963.

Gagne, R.M. *The Conditions of Learning.* (2nd ed.), Holt, Rinehart and Winston Inc., 1970.

Gallagher, J. "Research on Laboratory Work." *Science Education* 71(3), 351-355, 1987.

Gardner, P.L. "Attitude to Science: a Review." *Studies in Science Education* 2 , 1-41, 1975.

Gauld, C.F. and Hukins, A.A. "Scientific Attitudes: a Review." *Studies in Science Education* 7 , 129-161, 1980.

Hashweh, M.Z. "Toward An Explanation of Conceptual Change." *European Journal of Science Education* 8(3), 229 - 249, 1986.

Hashweh, M.Z. "Descriptive Studies of Students Conceptions in Science." Journal of Research in Science Teaching 25(2), 121-134, 1988.

Hellingman, C. "A Trial List of Objectives of Experimental Work in Science Education." European Journal of Science Education 4(29), 29-43, 1982.

Hincksman, N.G. "The Function of the School Laboratory." The Australian Science Teachers Journal 19, 81-86, 1973.

Hofstein, A., Ben-Zvi, R., Samuel, D. "The Measurement of Interest In, and Attitude to Laboratory Work Amongst Israeli High School Students." Science Education 60, 401-411, 1976

Hofstein, A. and Lunetta, V.N. "The Role of the Laboratory in Science Teaching: Neglected Aspects of Research." Review of Educational Research 52(2), 201-217 Summer, 1982

Hurd, P.D. and Rowe, M.B. "A Study of Small Group Dynamics and Productivity in the BSCS Laboratory Block Program." Journal of Research in Science Teaching 4, 67-73, 1966.

Inhelder, B. and Piaget, J. The Growth of Logical Thinking from Childhood to Adolescence. New York: Basic Books, Inc. 1958.

Johnson, D.W. "Student-Student Interaction: The Neglected Variable in Education." Educational Researcher 10(1), 5-10, 1981.

Johnson, R.I., Ryan, F.L., Schroeder, H. "Inquiry and the Development of Positive Attitudes." Science Education 58, 51-56, 1974.

Kempa, R.F. and Dynan, M.B.C. "Teacher - Based Assessment of Practical Work in Sixth-Form Physics." Physics Education 12(6), 1977.

Kerr, J.R. Practical Work in School Science. Leicester, England: Leicester University Press, 1963.

Klopfer, L.E. "Evaluation of Learning in Science." in Handbook on Formative and Summative Evaluation of Student Learning. (Bloom, B.S. et al.) McGraw-Hill Inc. 1971.

Kozlow, M.J. and Nay, M.A. "An Approach to Measuring Scientific Attitudes." Science Education 60(2), 147-172, 1976.

Kruglak, H., "A Comparison of the Conventional and Demonstration Method in the Elementary College Physics Laboratory" Journal of Experimental Education. 20, 293-300, 1952.

Kruglak, H., "Achievement of Physics Students With and Without Laboratory Work" American Journal of Physics. 21, 14-16, 1953.

Kruglak, H. and Wall, C.N. Laboratory Performance Tests for General Physics, Michigan, U.S.A. Western Michigan University, 1959.

Lecompte, M.D. and Goetz, J.P. "Problems of Reliability and Validity in Ethnographic Research" Review of Educational Research 52(1), 31-60, 1982.

Lehman, J.R., "Chemistry Teachers' and Chemistry Students' Perceived Advantages and Disadvantages of High School Chemistry Laboratories." School Science and Mathematics 89(6), 510-514, 1989.

Leonard, W.H. "Laboratory Instruction Is On Trial" The American Biology Teacher 43(8), 445-447, 1981.

Lunetta, V. and Tamir, P. "Matching Lab Activities With Teaching Goals." The Science Teacher 46(5), 22-24, 1979.

Lunetta, V. and Tamir, P. "An Analysis of Laboratory Activities: Project Physics and PSSC." School Science and Mathematics 81(8), 635-642, 1981.

Lynch, P.P. and Ndyetabura, V.L. "Practical Work in Schools: An Examination of Teachers' Stated Aims and the Influence of Practical Work According to Students." Journal of Research in Science Teaching 20(7), 663-671, 1983.

McCloskey, M., Caramozza, A., Green D. "Curvilinear Motion In the Absence of External Forces: Naive Beliefs About the Motion of Objects." Science 210, 1139-1144, December 1980.

McMillan, J.H. and May, M.J. "A Study of Factors Influencing Attitudes Toward Science of Junior High School Students." Journal of Research in Science Teaching 16(3), 217-222, 1979.

Moore, R.W. and Sutman, F. "The Development, Field Test and Validation of An Inventory of Scientific Attitudes." Journal of Research in Science Teaching 7 , 85-94, 1970.

Nadeau, R.J. "Inquiry Teaching in The Chemistry Laboratory." Unpublished Master of Education Thesis, The University of Alberta, 1984.

Nagalski, J.L. "Why 'Inquiry' Must Hold its Ground." The Science Teacher 47(4), 26-27, 1980.

Nay, M.A. "Characterization of An Inquiry Lesson" SCAT BULLETIN 9, 12-16, 1970.

Nay, M.A. "The Use of the Laboratory in Science Teaching" Paper prepared at the University of Alberta, 1986.

Nay, M.A. and Associates "A Process Approach to Teaching Science." Science Education 55(2), 197-207, 1971.

Nedelsky, L. Science Teaching and Testing. Harcourt, Bruce, and World Inc., 1965

Oakley, W.F. and Crocker, R.K. "An Exploratory Study of Teacher Interventions in Elementary Science Laboratory Groups." Journal of Research in Science Teaching 17(5), 407-418, 1980.

Okebukola, P.A. "Science Laboratory Behavior Strategies Of Students Relative to Performance In And Attitude To Laboratory Work." Journal of Research in Science Teaching 22(3), 221-232, 1985.

Piaget, J. The Group of Consciousness . Harvard University Press, Cambridge, 1976.

Posner, G., Strike, K., Hewson, P. and Gertzog, W. "Accommodation of A Scientific Conception Toward A Theory of Conceptual Change." Science Education 66(2), 211-227, 1982

Raghubir, K.P. "The Laboratory Investigative Approach to Science Instruction." Journal of Research in Science Teaching 16, 13-18, 1979.

Ramsey, G.A. and Howe, R.W. "An Analysis of Research on Instructional Procedures in Secondary School Science." Part II - Instructional Procedures. The Science Teacher 36(4), 1969.

Renner, J.W. "The Laboratory in Science Instruction" reprinted in Renner J.W. and Stafford, D.G. Teaching Science in Secondary Schools, New York: Harper and Rowe, 1972.

Renner, J.W., Abraham, M.R., Birnie, H.H. "Beliefs About the Physics Laboratory." Science Education 69(5), 649-663, 1985.

Renner, J.W. Abraham, M.R., Birnie, H.H., "The Importance of the Form of Student Acquisition of Data in Physics Learning Cycles." Journal of Research in Science Teaching 22(4), 303-325, 1985.

Renner, J.W., Abraham, M.R., Birnie, H.H. "The Necessity of Each Phase of the Learning Cycle in Teaching High School Physics." Journal of Research in Science Teaching 25(1), 39-58, 1988.

Renner, J.W., Lawson, A.E., "Piagetian Theory and Instruction in Physics." The Physics Teacher 11(3), 165-169, 1973.

Ross, J.A. and Maynes, F.J. "Experimental Problem Solving: An Instructional Improvement Field Experiment." Journal of Research in Science Teaching 20(6), 543-556, 1983.

Schwab, J. "The Teaching of Science as Enquiry" in J.J. Schwab and P.F. Brandwein The Teaching of Science Cambridge, Massachusetts, Harvard University Press, 1964.

Shulman, L.S. and Tamir, P. "Research on Teaching in the Natural Sciences" in N.L. Gage (ed.) Second Handbook on Research in Teaching. Chicago: Rand McNally and Co. 1118-1124, 1973.

Shymansky, J.A. "How is Student Performance Affected by the One-to-One Teacher-Student Interactions Occurring in An Activity-Centered Science Classroom?" Journal of Research in Science Teaching 13(3), 253-258, 1976.

Shymansky, J.A. and Penick, J.E. "Use of Systematic Observations to Improve College Science Laboratory Instruction" Science Education 63(2), 195-203, 1979.

Shymansky, J.A. and Penick, J.E. "Teacher Behavior Does Make a Difference In Hands-On Science Classrooms." School Science and Mathematics 81(5), 412-422, 1982.

Simpson, R.D., Oliver, S.J., "Attitude Toward Science and Achievement Motivation Profiles of Male and Female Science Students in Grade Six Through Ten." Science Education 69(4), 511-526, 1985.

Spradley, J.P. Participant Observation Holt, Rinehart and Winston, New York, 1980.

Stawinski, W., "Research Into the Effectiveness of Student Experiments in Biology Teaching." European Journal of Science Education 8(2), 213-224, 1986.

Stepans, J., Beiswenger, R., and Dyche, S. "Misconceptions Die Hard" The Science Teacher 53(6), 1986.

Sund, R., Trowbridge, L.W. Teaching Science By Inquiry. Columbus, Ohio: Merrill, 1967.

Tamir, P. "How Are the Laboratories Used." Journal of Research in Science Teaching 14(4), 311-316, 1977.

Tamir, P. and Lunetta, V.N. "An Analysis of Laboratory Inquiries in the BSCS Yellow Version" The American Biology Teacher 40(6), 353-357, 1978.

Thelen, L.J. "Values and Valuing in Science." Science Education 67(2), 185-192, 1983.

Thompson, J.J. Practical Work in Sixth Form Science. Oxford: Oxford University Department of Educational Studies, 1976.

Tobin, K. "Pupil Outcomes From A Process Oriented Science Program." The Australian Science Teachers Journal 29(2), 33-37, 1983.

Tobin, K. "Research on Science Laboratory Activities: In Pursuit of Better Questions and Answers to Improve Learning." School Science and Mathematics 90(5), 403-417, 1990.

Tobin, K. "Secondary Science Laboratory Activities." European Journal of Science Education 8(2), 199-211, 1986.

Tobin, K. "Student Task Involvement in Activity Oriented Science." Journal of Research in Science Teaching 21(5), 469-482, 1984.

Van Praagh, G. "Experiments in School Science." School Science Review 64 , 635-640, 1983.

Watson, F.G. "Assessment of Practical Work" In Jones, J.G. and Lewis, J.L. (eds.) The Role of the Laboratories in Physics Education Proceedings of the International Research Group on Physics Teaching Conference, Oxford, U.K., 1978.

Welch, W.W. Synthesis and Future Research. Symposium paper on the Role of Laboratory in Science Teaching. National Association for Research in Science Teaching. Boston, April, 1980.

West, G.W. "Participant Observation in Canadian Classrooms: The Need, Rationale, Techniques, and Development Implications." Canadian Journal of Education 2(3), 55-74, 1977.

Wilson, S. "The Use of Ethnographic Techniques in Educational Research." Review of Educational Research 47(1), 245-265, 1977.

Woolnough, B.E. "Practical Work in Sixth-Form Physics." Physics Education 11(6), 1976.

Woolnough, B.F. and Allsop, T. Practical Work In Science. Cambridge University Press, Great Britain, 1985.

Yager, R.E., Engen, H.B., Snider, C.F. "Effects of the Laboratory and Demonstration Methods Upon the Outcomes of Instruction in Secondary Biology." Journal of Research in Science Teaching 5, 76-86, 1969.

Yager, R.E., "Assess All Five Domains of Science." The Science Teacher 54(7), 33-37, October, 1987.

APPENDICES

APPENDIX A

AN INVENTORY OF PROCESSES IN SCIENTIFIC INQUIRY

AN INVENTORY OF PROCESSES IN SCIENTIFIC INQUIRY

(Nay et al., 1971)

I INITIATION

1. Identifying and formulating a problem
   - (a) speculating about a phenomenon
   - (b) identifying variables
   - (c) noting and making assumptions
   - (d) delimiting the problem

2. Seeking background information
   - (a) recalling relevant knowledge and experiences
   - (b) doing literature research
   - (c) consulting people

3. Predicting

4. Hypothesizing

5. Designing collection of data through field work and/or experimentation
   - (a) defining the independent, dependent, and controlled variables
   - (b) defining the procedure and sequencing the steps
   - (c) identifying needed equipment, materials and techniques
   - (d) indicating safety precautions
   - (e) devising the method of recording data

II COLLECTION OF DATA

6. Procedure
   - (a) collecting, constructing, and setting up the apparatus or equipment
   - (b) doing field work and/or performing the experiment
   - (c) identifying the limitations of the design (as a result of failures, blind alleys, etc.) and modifying the procedure (often by trial-and-error)
   - (d) repeating the experiment (for reproducibility, to overcome limitations of initial design, and more)
   - (e) recording data (describing, tabulating, diagramming, photographing and so on).

7. Observing and observations
   - (a) obtaining qualitative data (using senses)
   - (b) obtaining semi-quantitative and quantitative data

  - (c) gathering specimens
  - (d) obtaining graphical data (charts, photographs, films, etc.
  - (e) noting unexpected or accidental occurrences (serendipity)
  - (f) noting the precision and accuracy of data
  - (g) judging the reliability and validity of data

III PROCESSING OF DATA

8. Organizing the data

  - (a) ordering to identify regularities
  - (b) classifying
  - (c) comparing

9. Representing the data graphically

  - (a) drawing graphs, charts, maps, diagrams
  - (b) interpolating, extrapolating, etc.

10. Treating the data mathematically

  - (a) computing (calculating)
  - (b) using statistics
  - (c) determining the uncertainty in the results

IV CONCEPTUALIZATION OF DATA

11. Interpreting the data

  - (a) suggesting an explanation for a set of data
  - (b) deriving an inference or generalization from a set of data
  - (c) assessing validity of initial assumptions, predictions, and hypotheses

12. Formulating operational definitions

  - (a) verbal
  - (b) mathematical

13. Expressing data in the form of a mathematical relationship

14. Incorporating the new discovery into the existing theory (developing a "mental model")

V. OPENENDEDNESS

15. Seeking further evidence to:

(a) increase the level of confidence in the explanation or generalization
(b) test the range of applicability of the explanation or generalization

16. Identifying new problems for investigation because of:

(a) the need to study the effect of new variables
(b) anomalous or unexpected observations
(c) incompleteness ("gaps") and inconsistencies in the theory.

17. Applying the discovered knowledge.

APPENDIX B

A SCIENTIFIC PROCESS SKILLS ANALYSIS MODE

(NADEAU, 1984)

TABLE __

Lab __ Title: ____________________

Key: S=initiated by student, T=guidance provided by teacher, M=guidance provided by laboratory manual

PROCESSES	STRUCTURING	COMMENTS
1. IDENTIFYING AND FORMULATING A PROBLEM		
(a) speculating		
(b) identifying variables		
(c) making assumptions		
(d) delimiting problem		
2. SEEKING BACKGROUND INFORMATION		
(a) recalling experiences		
(b) doing literature research		
(c) consulting people		
3. PREDICTING		
4. HYPOTHESIZING		
5. DESIGNING COLLECTION OF DATA		
(a) defining variables		
(b) defining experimental steps		
(c) equipment and techniques		
(d) safety		
(e) method of recording data		
6. COLLECTION OF DATA		
(a) setting up apparatus		
(b) performing experiment		
(c) modifying procedure		
(d) repeating experiment		
(e) recording data		
7. OBSERVING AND OBSERVATIONS		
(a) qualitative data		
(b) quantitative data		
(c) gathering specimens		
(d) graphical data		
(e) serendipity		
(f) accuracy of data		
(g) reliability and validity		
8. ORGANIZING THE DATA		
(a) ordering		
(b) classifying		
(c) comparing		

TABLE (Cont'd)

PROCESSES	STRUCTURING	COMMENTS
9. REPRESENTING THE DATA GRAPHICALLY (a) graphs, diagrams, ...		
(b) interpolating, extrapolating		
10. TREATING DATA MATHEMATICALLY (a) calculating		
(b) using statistics		
(c) uncertainty of results		
11. INTERPRETING THE DATA (a) explanation of data		
(b) generalization or inferences		
(c) assessing validity of predictions		
12. FORMULATING OPERATIONAL DEFINITIONS (a) verbal		
(b) mathematical		
13. EXPRESSING DATA IN THE FORM OF A MATHEMATICAL RELATIONSHIP		
14. INCORPORATING THE NEW DISCOVERY INTO EXISTING THEORY		
15. SEEKING FURTHER EVIDENCE TO: (a) increase confidence		
(b) test generalizability		
16.. IDENTIFYING NEW PROBLEMS FOR INVESTIGATION BECAUSE OF: (a) effect of new variables		
(b) unexpected observations		
(c) inconsistencies in theory		
17. APPLYING THE DISCOVERED KNOWLEDGE		
TOTAL NUMBER OF SUBSKILLS		
INITIATED BY STUDENT		

APPENDIX C

A MODIFIED VERSION OF FISHER'S SCIENCE OPINIONNAIRE

(Keyed)

(Questions 21-30 inclusive have been added for purposes of the current study.)

SCIENCE OPINIONNAIRE

MALE ______ FEMALE _____

Please check the answer that most agrees with how you feel about science at this school. Answer how you feel and not how you think you should feel.

Do not sign your name.

1. Reading science is difficult.

1	2	3	4	5
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

2. We spend too much time doing experiments.

1	2	3	4	5
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

3. I am learning a lot in science this year.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

4. What we do in class is what a real scientist would do.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

5. In science class we study "today's problems."

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

6. I dislike coming to science class.

1	2	3	4	5
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

7. I read more science materials than I did in sixth grade.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

8. I enjoy doing the science experiments.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

9. I can solve problems better than before.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

10. My friends enjoy doing science experiments.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

11. What I am learning in science will be useful to me outside school.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

12. I think about things we learn in science class when I'm not in school.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

13. I do not want to take any more science classes than I have to take.

1	2	3	4	5
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

14. Reading science is more fun than it used to be.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

15. Experiments are hard to understand.

1	2	3	4	5
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

16. Science is dull for most people.

1	2	3	4	5
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

17. The things we do in this class are useless

1	2	3	4	5
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

18. The kinds of experiments I do in the class are important.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

19. I learn a lot from doing my science experiments.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

20. Most people like science classes.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

21. I get actively involved in performing the laboratory experiments.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22. Most students discuss their data and findings within their laboratory groups.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

23. The members within my lab group do the labs without getting into arguments.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24. I enjoy working with my lab partners.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

25. Working with my lab partners often assists me in getting a better understanding of the experiment and its interpretation.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

26. Class discussions and demonstrations before the laboratory are helpful.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

27. Laboratory experiments should not have so many instructions in order to allow students to think more about how to do the experiments.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

28. Without class discussions after the laboratory, experiments would be a waste of time.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

29. Teachers provide students with too much help during laboratory activities.

5	4	3	2	1
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

30. Complete this sentence any way you wish. Write on this paper.
I think science laboratory work is

APPENDIX D

SCIENCE LABORATORY INTERACTION CATEGORIES (SLIC)

SCIENCE LABORATORY INTERACTION CATEGORIES (SLIC) - Student

Developed by J.A. Shymansky, J.E. Penick, K. Filkins, and W.C. Kyle, Jr. of the Science Education Center, University of Iowa. (1979)

S--- Shows; manipulating materials with the purpose of transmitting information to teacher or student; includes showing how to do something as well as demonstrating the result of doing something.

E--- Manipulates apparatus, observes activity; experimenting, manipulating equipment, observing experiment in progress; other activity with lesson-related non-written materials.

T--- Transmits information; conveying ideas, thoughts, questions without manipulating equipment. Includes giving directions, feedback, answering questions, or other behavior which transmits information. Includes rhetorical questions.

Q--- Asks questions; any attempt to gather information verbally from teacher or students.

L--- Listens; active behavior of receiving information from teacher or student.

O--- Observes; passive behavior allowing student to watch actions of teacher or students; includes listening to conversations in which the subject is not directly involved.

R--- Reads lesson-related materials; any reading related to the lesson or course goals; includes notes that have been written by the student, notes written by another student, a textbook or lab manual.

W--- Writes notes or records data; note taking, recording of data, answering of questions, or other writing directly related to the lesson; does not involve transmitting information immediately to another person.

M--- Gets supplies, moves around the room; moving around the room in a purposeful fashion, getting supplies, putting away materials, or other mobile activities which facilitate the lesson.

Z--- Non-lesson-related behavior; behavior which does not facilitate the goals of the particular course or lesson, including interactive as well as non-interactive behaviors.

Check List Used For Science Laboratory Interaction Categories (SLIC) - Student

S (1) Shows: manipulating materials with purpose of transmitting information.

E (2) Manipulates apparatus, observes activity.

T (3) Transmits information (convey ideas, thoughts without manipulating equipment.

Q (4) Asks questions (any attempt to gather information verbally).

L (5) Listens (active behaviour of receiving information)

O (6) Observes (passive behaviour allowing students to watch actions of others).

R (7) Reads lessons - related materials.

W (8) Writes notes or records data.

M (9) Gets supplies, moves around the room (in a purposeful fashion).

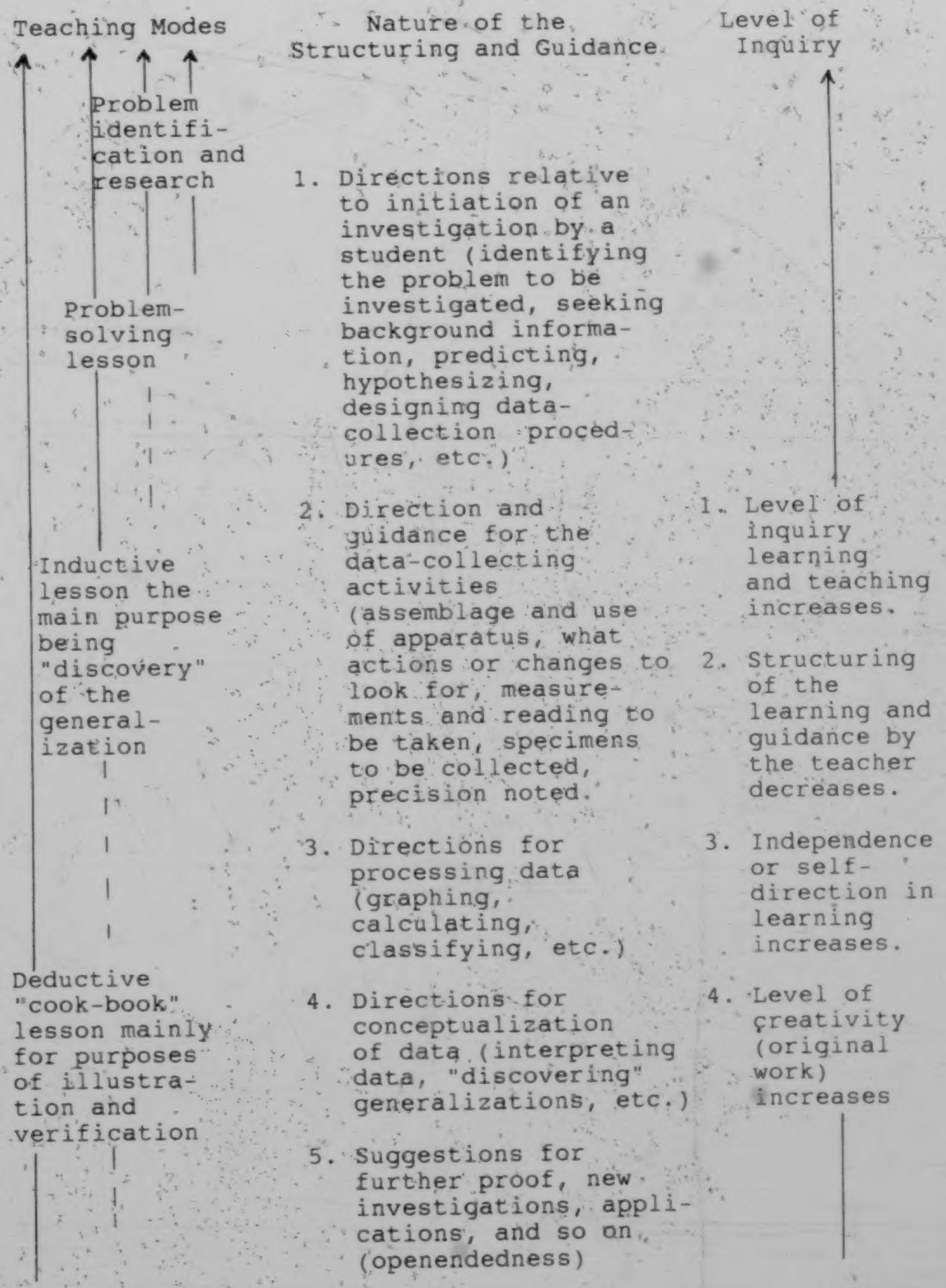
Z (10) Non-lesson - related behaviour (both interactive and non-interactive).

APPENDIX E

CHARACTERIZATION OF AN INQUIRY LESSON CHART

(NAY, 1970)

CHARACTERIZATION OF AN INQUIRY LESSON



Teaching Modes

Problem identification and research

Problem-solving lesson

Inductive lesson the main purpose being "discovery" of the generalization

Deductive "cook-book" lesson mainly for purposes of illustration and verification

Nature of the Structuring and Guidance

1. Directions relative to initiation of an investigation by a student (identifying the problem to be investigated, seeking background information, predicting, hypothesizing, designing data-collection procedures, etc.)
2. Direction and guidance for the data-collecting activities (assemblage and use of apparatus, what actions or changes to look for, measurements and reading to be taken, specimens to be collected, precision noted.
3. Directions for processing data (graphing, calculating, classifying, etc.)
4. Directions for conceptualization of data (interpreting data, "discovering" generalizations, etc.)
5. Suggestions for further proof, new investigations, applications, and so on (openendedness)

Level of Inquiry

1. Level of inquiry learning and teaching increases.
2. Structuring of the learning and guidance by the teacher decreases.
3. Independence or self-direction in learning increases.
4. Level of creativity (original work) increases

APPENDIX F

THE THREE PHASES OF LABORATORY ACTIVITY

(NAY, 1986) unpublished brj.

The Use of the Laboratory in Science Teaching

The Three Phases of Laboratory Activity

prepared by M.A. Nay (1986)

I Pre-laboratory activity (pre-laboratory phase):
- teacher planning and preparation
- student preparation (in class and/or for homework)
- in-class activity

II Laboratory activity (laboratory phase):
- students perform the experiment/investigation
- teacher supervises, etc.

III Post-laboratory activity (post-laboratory phase):
- students write reports, etc.
- reports are marked and returned to students
- discussion of the completed students' experiment/investigation in class
- evaluation of the laboratory activity

I Pre-laboratory Activity

1. Teacher planning and preparation:

(a) Prepares a comprehensive lesson plan (as part of a unit plan) covering all three phases of the laboratory lesson, including the logistics of space and equipment.

(b) Reserves laboratory space (if necessary), and assistance of the lab aide (assistant).

(c) Makes necessary arrangements if field work is involved.

(d) The teacher and/or laboratory assistant collects materials (apparatus, reagents, live specimens, etc.) and checks and repairs them (if necessary). Some of the materials to be used by students may be sorted into tote boxes (kits) or distributed to the laboratory stations. Some chemical solutions may have to be prepared in advance. Complex or fragile equipment may have to be assembled/connected.

(e) Does the experiment beforehand if not familiar with it (to determine potential problems in technique, time required, etc.), or if needs to check the operation of the materials.

(f) Prepares handouts and transparencies, obtains audio-visual materials (e.g. a filmloop to demonstrate a technique), etc.

(g) Identifies beforehand in class the idea or problem to be investigated (perhaps on the basis of the previous lesson or topic). May assign the experiment to be read (in class and/or for homework), and may have the students prepare a preliminary report (e.g., problem statement, hypothesis, experimental design). May also guide students to appropriate reference material.

2. Student Preparation for Laboratory Work

(a) May be asked for input in planning investigation (what and how to investigate), hence students may have to do some literature research.

(b) Reads the assigned experiment and writes up the necessary preliminary process steps of the report (see #1 g above).

(c) Collects and brings materials to class (if asked by the teacher).

(d) obtains permission, money, etc. from a parent/guardian if out-of-school activity is involved.

3. In-Class Activity :

(a) Teacher checks up on how well students prepared for the laboratory activity by means of one or more of the following:

- Administering a short pre-laboratory test.
- Checking the write-ups of the preliminary report (see #1 g above).
- Questioning during the pre-laboratory discussion.

(b) Pre-laboratory discussion (which may include demonstrations and/or use of audiovisual materials):

- The teacher may lecture on and/or discuss various aspects of the investigation to be done.*

Some of these are as follows:

(i) The purpose of the experiment may be discussed and how it arises from previous work taken up in class.

(ii) Review/discuss/lecture on the conceptual background or theory needed for the investigation.

(iii) Go through some (or even all) of the steps in the laboratory manual or handout. In particular the teacher will clarify/demonstrate/illustrate techniques and apparatus which are new to the students, and the use and care of unfamiliar equipment. Audio-visual aids may be used instead of live demonstrations. The teacher may give additional instructions, questions to be answered and precautions to those already in the manual, and may even suggest modifications in design.

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* How much is told, discussed or revealed in class depends on the level of inquiry the teacher decides is appropriate for the investigation. The teacher should determine beforehand what should be discussed, reviewed or added in class, and what the students should find out for themselves in the course of doing the experiment.

- Reviews ground rules on laboratory behavior (including safety precautions). Gives special attention to hazards involved in the use of unfamiliar materials/equipment.
- If a high level of inquiry is used in which students are required to hypothesize, design an experiment and so forth, the teacher will want to check on their preliminary work on these process skills. Through discussion of the various student designs a "Class Design" may be developed which all students follow. (On the other hand, once in a while the teacher may allow each student to follow own design, but only if the teacher has accepted it).
- The teacher gives explicit instructions regarding follow-up activities to the laboratory phase: format of the report, what information to include, questions to be answered, when to hand reports in, etc.
- Throughout the pre-laboratory discussion the teacher asks for and deals with questions from students and difficulties that they have encountered in preparing for the laboratory work.
- Teacher will group the class for the investigation (if this has not been done yet).

II Laboratory Activity

1. The teacher or the assistant turns on master values and switches for the utilities.

2. (a) Students go into the laboratory area, gather in their groups at a station (which may be designated by the teacher), and work on the investigation in a serious manner. Depending on instructions from the teacher, they will follow the procedure (design) in the laboratory manual or handout, class design or their own design. Data are recorded in their notebooks. The teacher may require the group

to submit a duplicate copy of the data when the experiment is finished.

(b) When the group finishes the experimental work, the laboratory station is cleaned up (equipment and materials are washed and put away as instructed, the bench top is washed, water and other utilities are shut off, etc.)

(c) The students then go to a seating area where they work on the laboratory report until the end of the period.

3. The teacher supervises, guides, manages, and evaluates the laboratory activities.

(a) Supervision

- Making sure that all groups are working and that a reasonable effort is coming from each member.
- Making sure each group is progressing at a satisfactory pace.
- Checking on the proper use of techniques, experimental steps, precautions, etc.
- Making sure that data are being recorded properly by each member of the group.
- Encouraging and stimulating students to greater effort.
- Having students repeat work if results not satisfactory.

(b) Guidance:

- Helping the group/individuals with difficulties regarding assembly of apparatus, techniques, steps in the experiment, etc. (more by questioning and cues than by telling).
- Further clarifying of instructions to the whole class.
- Giving positive reinforcement (e.g. praise).

- Leading students to observations they have missed.

(c) Management:

- Minimizing hazards and attending to accidents (HIGHEST PRIORITY).
- Maintaining an appropriate laboratory atmosphere: enforcing discipline, curtailing socializing and tomfoolery, etc.
- Trouble-shooting: helping with apparatus failure, replacing or repairing broken equipment, providing equipment not put out beforehand, etc.
- Checking to see that equipment, bottles of reagent, etc. are returned to the designated places during the laboratory activity and clean-up.
- Having students work productively (e.g., work on laboratory report) during "dead intervals" e.g., a solution is being heated to dryness, a precipitate is being filtered).
- Reminding the class again as to what is required in the way of a report, when it is to be handed in, etc.
- Checking on the clean-up by groups who are finished.
- Checking on the groups who are at their seats working on the reports.
- Dismissal at the end of the period.
- Checking equipment, reagents, etc. at the end of the laboratory activity, and returning them to their appropriate storage area.

(d) Evaluation

- Getting further feedback on the level of preparation of individual students for the laboratory activity by observing and questioning them.

- Getting feedback on what students are learning, difficulties being experienced, etc. (through listening, observing, questioning students, receiving questions from students, etc.).

- Checking on the reliability and validity (precision and accuracy) of student's data.

- Assessing whether or not the objectives of the laboratory activity are being achieved.

- Determining student attitude towards experimental work and making entries into anecdotal records.

III Post-laboratory Activity

1. Students write reports, etc. (in class or for homework) and hand in by deadline (if requested).

2. Reports etc. are marked:

   (a) By students in class.

   (b) By the teacher. Time is a critical factor in marking reports in two ways: reports are time-consuming to mark, and they should be returned to students as soon as possible after the laboratory phase. Therefore teachers should develop a practical policy regarding marking reports, taking into account considerations such as the following:

   - How many reports should be marked carefully by the teacher and which ones?

   - What report format should be followed (e.g., how many process skills should be included, should the ones given in the manual or handout be repeated on the report)?

   - What are the main things to look for in the report?

   - How much written comment is desirable/necessary (remembering that the investigation will be taken up in class)?

3. Post-laboratory discussion (the main purpose of which is to give students a chance to catch up on anything missed or correct anything in their report that is wrong):

(a) Returning the marked reports in class and making some general comments about them:

- How marks were assigned to different parts of the report (i.e., distribution of marks).
- Range of marks obtained by students.
- Parts which were well done/poorly done and probable reason for parts that were poorly done.
- Procedure for appealing the mark.

(b) Discussing the completed laboratory investigation in class. Some general guidelines for this discussion are as follows:

- Indicate to students that they should correct their reports during the discussion and add missing ideas.
- Follow the steps as outlined in the laboratory manual or investigation handout (See Appendix below for ideas).
- Take up all questions posed in the manual or handout.
- Use student input where-ever possible; that is, use their data, answers to questions, predictions, interpretations, etc.
- Use transparencies, chalkboard lists and summaries, etc. where clarification will be enhances by audiovisual input.
- Use this discussion as an opportunity for students to practice, enhance understanding and apply scientific process skills. (See Appendix below for ideas).
- Relate concepts learned to past lessons

and future work.

(c) For some investigations may require oral reports, display of materials, etc.

4. Post-laboratory evaluation

(a) Marking and discussion of reports (see above).

(b) Determining whether objective of the investigation was achieved. If it was not, determine what modifications have to be made in using the investigation more effectively - or should it be discarded?

(c) Assessing how well the investigation is functioning in terms of available time and equipment, level of preparation of students, clarity and simplicity of the experimental steps, etc.

(d) Administering laboratory tests: paper-and-pencil type, practical examination, task analysis, etc.

(e) Writing anecdotal comments on each student (e.g., regarding attitude towards laboratory work, preparedness).

APPENDIX

Examples of questions/aspects to which attention should be given in a post-laboratory discussion. The Inventory of Scientific Process Skills by Nay et al is used as a basis for organizing the discussion.

1. Problem identification and definition. (This would usually be done during the pre-laboratory discussion, but a review at the post-laboratory stage is necessary.)

   - Statement of the problem. Where did it originate?

   - Variables involved: manipulated, responding, controlled.

   - Were some new variable identified during the investigation?

   - Assumptions, if any, made about some of the variables.

2. Background information

   - What knowledge was required to formulate the problem, design an experiment and interpret the data?

   - How did this knowledge help in regard to each process skill?

3. Hypotheses (may have done this during the
4. Predictions pre-laboratory discussion.)

   - Review/list students' hypotheses/predictions.

   - Compare the hypotheses/predictions, note the frequency with which each is made by the groups, and assess their validity in the light of the preliminary evidence.

   - Note operational (working) hypotheses and their significance for the experimental design.

5. Designing an experiment
6. Experimental procedure

   - Did everything go as planned? What difficulties or problems occurred, how did they affect the results, and what was done to overcome them. Limitations of original design?

- Reasons for some of the steps and precautions (those not taken up in the pre-laboratory discussion).
- Did anyone have to repeat a part or all of the experiment? Why?
- Any suggestions for improving the experimental procedure?
- Was replication (reproducibility) of data necessary? Why or why not?

7. Observations
8. Organizing data

- Listing of all observations so that students can add what they missed.
- Any unexpected observations?
- Differentiating between qualitative, semi-quantitative and quantitative data.
- How well do the observations seem to represent the problem being investigated?
- Systematization of data by means of a table or classification scheme. Reasons for using this method of systematizing data; that is, how does it help to interpret data (e.g., shows trends)?
- Collation and comparison of class results on the chalkboard or transparency. Why? Discuss accuracy and reliability of data.
- Compare methods of classification used by groups. What frame of reference was used by each?

9. Graphing

- Comparison of graphs of groups. Why was the specific graphing format chosen?
- What do the graphs mean (that is, the relationship between the manipulated and responding variables)?
- Any interpolations and extrapolations warranted?
- How is the graphing helpful in making sense (interpretation) of the data?

10. Mathematical treatment

- Averaging of collated data. What to do about results which differ significantly from the class mean?

- Comparing the calculated experimental values with those reported in the textbooks.

- Discussion of sources of errors/calculation of errors.

- How does the mathematical treatment help in making sense of the data?

11. Interpreting the data

    - Which hypothesis or prediction is supported best?

    - Any variation in interpretation of data among the groups? What observations were used/given emphasis in each interpretation?

    - Has too little or too much been read into the observations? Level of certainty?

    - Is the interpretation a satisfactory answer to the problem?

    - Discussion of the new concept derived experimentally and how it fits with previous work done.

12. Formulating operational definitions

    - Identify the operational definitions used in solving the problem; formulating new ones as a results of the investigation.

13. Deriving a mathematical relationship

    - Identify the mathematical relationship used in solving the problem; formulating a new one as a result of the investigation.

14. Theory-building

    - How can we use our interpretation of the observations to expand or validate the background theory.

    - Relate the new knowledge to what the students knew before they did the experiment.

15. Seeking further evidence

- What is the "level of certainty" that can be placed on the knowledge gained in this experiment? How can this level be increased; that is, better data be obtained.

- Suggest alternative procedures or other experiments which could provide further evidence for the knowledge discovered in this experiment.

- More similar mathematical problems to solve (DRILL).

16. Identifying new problems

    - What new problems can be undertaken that are connected to the one just solved (e.g., relationship between other variables)?

    - Did any anomolous behavior appear in the investigation which can be studied experimentally?

17. Applying discovered knowledge

    - Relationship to the next topic to be studied.

    - Application to everyday life.

APPENDIX G

SUMMARY OF RESEARCHER FIELD NOTES

TABLE 11

SUMMARY OF RESEARCHER FIELD NOTES FOR ARFVEDSON SCHOOL

(GRADE 7)

Investigation 1: One kind of Food Produced by Green Plants

Topic	Summary of Researcher Notations
Science Opinionnaire (Period 1)	Students responded to science opinionnaire statements taking twenty minutes of the class period.
Background Information	Students given class time to read p.257-261 of "Life Science, A Problem Solving Approach" reference book. This reading was used to introduce the class to photosynthesis.
Pre-Lab Activity	Teacher handed out a worksheet consisting of 6 questions. Students to answer questions using the reading done in the reference book.
Pre-Lab Activity Continued (Period 2)	Students given class time to continue working on 6 questions of photosynthesis worksheet. This worksheet was collected for marking.
Pre-Lab Discussion	Teacher introduced investigation 1, to the end of procedure Part B (heating Benedict's solution with green onion tops). Students required to write out problem, and copy out a chart for recording observations as put on the board by the teacher.
Lab Groups	Students worked in groups determined by how they had picked their seats around the lab tables.
Lab Work	Students performed part A and B of the investigation.

TABLE 11 (Cont'd.)

Topic	Summary of Researcher Notations
Teacher Activity During Lab Work	Both the intern and regular teacher moved around the classroom to assist students in lighting their bunsen burners and performing their experiments as needed. Researcher observed selected students with SLIC checklist.
Pre-Lab Discussion (period 3)	Teacher introduced and demonstrated procedure for part C of the investigation.
Lab Work	Students performed Part C of investigation.
Post-Lab Activity	Students began to answer inference questions provided for the investigation. Students to answer questions so that the answer includes the question being asked. Researcher interviewed two of the selected students.
Post-Lab Activity Continued (Period 4)	Students continued working on inference questions for investigation 1. Researcher interviewed third selected student.
Post-Lab Discussion	Teacher discussed inference questions with the class. Sometimes, teacher read the question and asked students to give answer, other times students were asked to read questions and also give the answers. Teacher dictated correct answers to the class, and used the chalkboard to provide further explanations when necessary. The 3 students selected for observing with SLIC appeared to listen to the discussion, and made corrections to their notes.

TABLE 12

SUMMARY OF RESEARCHER FIELD NOTES FOR GRADE 7

Investigation 2: When Do Plant Leaves Contain Starch?

Topic	Summary of Researcher Notations
Pre-Lab Discussion (Period 1)	Teacher introduces laboratory investigation and demonstrates test for starch by using the following substances: flour, laundry starch, sucrose, corn starch, corn syrup, soda crackers, and vegetable oil. Students recorded results.
Pre-Lab Discussion Continued (Period 2)	Teacher discussed results for demonstration done last period and provided background notes for investigation 2, and then introduced the procedure for this investigation including precautions required. Students asked to write out the problem.
Lab Work	Students performed part 1 of the investigation (sections A to G). Teacher assisted students as required. Researcher observed selected students with SLIC checklist.
Lab Work Continued (Period 3)	Students performed Part 2 of the investigation (with a green plant kept in the dark for 24 hours) after a brief review of procedure.
Post-Lab Activity	Students worked on inference questions as provided in the investigation. Students to complete questions for homework. Researcher interviewed selected students.
Post-Lab Discussion	Researcher not present.

TABLE 13

SUMMARY OF RESEARCHER FIELD NOTES FOR GRADE 7

Investigation 3: Internal Structure Of A Leaf (cross-section)

Topic	Summary of Researcher Notations
Pre-Lab Discussion (Period 1)	Students performed Parts A and B, previously, and therefore had used some of the needed techniques. Students had been asked to read procedure for Part C of lab as homework before coming to class. Teacher briefly discussed background information, making of a slide, and carrying and using a microscope.
Pre-Lab Activity	Some students asked to assist in bringing out the microscope from preparation room. Teacher prepared sample cross-section slides for students. Students asked to make observations in following order: observe prepared slides, make diagram, answer questions in section 6, make and observe their own slides, draw diagram.
Lab-Work	Students observed prepared slide, drew diagram, and prepared and observed their own slide of a leaf cross-section. Drew diagram of their cross-section. Researcher observed selected students with SLIC checklist.
Lab Work (Period 2)	Students finished performing of Investigation 3, as necessary.
Post-Lab Activity	Students worked on inference questions provided for the investigation. Researcher interviewed selected students.
Post-Lab Discussion	Researcher not present for Post-Lab discussion.

TABLE 14

SUMMARY OF RESEARCHER FIELD NOTES FOR CHADWICK SCHOOL

(GRADE 8)

Investigation 1 : Relative Density

Topic	Summary of Researcher Notations
Science Opinionnaire (Period 1)	In the first fifteen minutes of class students responded to the opinionnaire statements.
Background Information	The teacher wrote a formula for calculating relative density on the board and explained it. $\text{relative density} = \frac{\text{mass of object in air}}{\text{mass of an equal volume of water}}$ Students provided with a sample calculation. The teacher put a second formula for calculating relative density on the chalkboard and also explained it. $\text{relative density} = \frac{\text{mass of object in air}}{\text{apparent mass loss of object in water}}$ Students provided with a second sample calculation. Students asked to summarize the discussion of relative density in the "Challenges in Science - Earth Science" reference book. The teacher also handed out a worksheet on relative density (7 problems).

TABLE 14 (Cont'd.)

Topic	Summary of Researcher Notations
Pre-Lab Discussion (Worksheets) (Period 2)	Specific students asked to go to the chalkboard and to show their calculations for the relative density problems given last period. The teacher then discussed the calculations provided by students. Teacher introduced the laboratory investigation headings as outlined in students' notes. Students asked to begin preparing laboratory reports. Class time given to prepare pre-lab sections of laboratory reports (i.e. problem, background information, materials, charts, etc.). Students worked very quietly in preparing their lab reports during the class period.
Pre-Lab Discussion (Period 3)	Teacher introduced the procedure for performing the investigation. Students were shown techniques for: balancing and using a triple beam balance, hooking string to bottom of balance, and placing balances over edge of lab tables. Most of the students had not used a triple beam balance before.
Lab Groups	Students pick up a group card from the counter, and leave it in a box provided as they pick up required materials. Teacher previously assigned students to lab groups.
Lab Work	As students performed their investigation, the teacher assisted students as required, and evaluated students' behavior and performance levels. The researcher observed interactions of selected students using SLIC checklist. More time needed to complete performing of investigation next period.

TABLE 14 (Cont'd.)

Topic	Summary of Researcher Notations
Lab Work (Period 4)	Students completed performing of relative density investigation. Researcher continued observation of selected students with SLIC checklist.
Lab Clean-Up	One group of students, each lab, is assigned to check if lab tables have been cleaned up, and if equipment has been put back into its proper location.
Post-Lab Discussion	Teacher explains use of calculations chart, as provided in laboratory notes. Students to complete this chart for homework.
Post-Lab Activity (Period 5)	Students given class time to prepare post-lab sections of laboratory reports (i.e. interpretations). Lab reports to be handed in next period. Researcher interviewed the selected students.
Post-Lab Discussion	Researcher did not observe, since done after lab reports returned.

TABLE 15

SUMMARY OF RESEARCHER FIELD NOTES CHADWICK SCHOOL (GRADE 8)

Investigation 2: Identification of Minerals

Topic	Summary of Researcher Notations
Pre-Lab Discussion (Period 1)	Teacher introduced laboratory investigation, and indicated what students are do do in filling in chart. Teacher reviewed previously used identification tests needed in mineral identification: color, luster, streak, and hardness.
Lab Work	Students given time in class to fill in data chart with information collected in previous investigations (i.e. color, luster, streak, hardness) for mineral numbers used in the investigation. Students began to determine relative density for minerals provided, need to continue next period. Researcher observed selected students with SLIC checklist.
Lab Work	After a brief teacher review of laboratory procedure for finding relative density, students continued with performing of Investigation 2. Researcher interviewed selected students as they completed performing their investigation.
Post-Lab Activity	Students identified mineral samples by using characteristics determined and a provided mineral identification chart.
Post-Lab Discussion	Not observed, researcher scheduled at another school.

TABLE 16

SUMMARY OF RESEARCHER FIELD NOTES FOR ASTON SCHOOL (GRADE 9)

Investigation 1: How May Elements Be Distinguished By Flame Tests?

Topic	Summary of Researcher Notations
Administering of Opinionnaire	In the first fifteen minutes of the class period students responded to the science opinionnaire.
Pre-Lab Discussion (Period 1)	During the pre-laboratory discussion the teacher reviewed lab safety precautions, including technique for lighting of a bunsen burner and introduced the procedure of Investigation 1.
Lab Groups	For purposes of this investigation the class was divided into six lab groups, based upon their seating location within the class. Most groups consisted of 4 members.
Performing Experiment	During approximately the last 15 minutes of the class period students began to work on this investigation. To complete next period.
Activity of Teacher During Lab	While students worked on the laboratory investigation the teacher circulated around the room assisting students as needed.
Brief Review (Period 2)	At the beginning of the next period the teacher reviewed the problem, procedure, etc. of the investigation by questioning students.
Continuation of Lab Work	Students continued with their laboratory work, researcher observed 3 selected students with SLIC checklist.

TABLE 16 (Cont'd.)

Topic	Summary of Researcher Notations
Interpretation of Lab Results	For about 10 minutes students worked on answering the inference questions provided in the investigation (only a few questions to answer). Teacher assisted students as required in doing the inference questions.
Post-Lab Discussion	During the last part of the period teacher discussed laboratory investigation 1. Teacher used chalkboard to help students understand inference responses. Individual students are asked to provide their answer to an inference question, after they have read the question aloud. Teacher then provides further explanations as needed. Students also ask questions of the teacher to obtain clarification and further understanding. Teacher assists students, as necessary, by providing demonstrations for illustrating inference question answers (e.g. used a piece of iron and piece of wood to illustrate question 4). Teacher also examines practical application for flame tests.

TABLE 17

SUMMARY OF RESEARCHER FIELD NOTES FOR ASTON SCHOOL (GRADE 9)

Investigation 2: Distinguishing Between a Mixture and a Compound

Topic	Summary of Researcher Notation
Pre-Lab Discussion (Period 1)	Teacher introduced and gave examples of the terms; element, mixture, and compound. Teacher introduced procedure for first part of investigation (to approximately step 4).
Performing of Lab	Students performed the first part of investigation. Researcher observed selected students with SLIC checklist.
Pre-Lab Discussion continued (Period 2)	Teacher clarified recording of data in chart A of the investigation, in response to a question asked by a student. Teacher then defined the term solubility and continued with the introduction of the procedure. Particular emphasis was placed on the technique for heating the iron-sulfur mixture. "Use small test tubes provided, heating will be done in the fume hood only, and by one group at a time".
Performing of Lab Completed	Students completed performing of investigation 2. As students became available the researcher began interviewing selected students.
Interpretation of Collected Data	Students began answering the questions provided for the investigation. While teacher assisted students as required. The researcher continued interviewing of the three selected students.
Post-Lab Discussion (Period 3)	As this discussion occurred in the following week, the researcher was unable to be present due to previous scheduling.

TABLE 18

SUMMARY OF RESEARCHER FIELD NOTES FOR ASTON SCHOOL (GRADE 9)

Investigation 3: To Separate and Identify as Many Components as Possible From a Mixture.

Topic	Summary of Researcher Notation
Pre-Lab Discussion for Open-ended Investigation (Period 1)	Teacher indicates to the class that this investigation is open-ended. "Last experiment in the series is not written up, you have to write it up using all the processes". Teacher dictates the problem to be solved to the class. "Problem: To separate and identify as many components (substances) as possible from the mixture." Students are to use the scientific process skill headings, as needed, to write up their reports. A chart of the scientific process skills is located on the west wall of the classroom to which students are referred.
Lab Groups	Students are directed to "get into groups to determine how to attack this problem."
Lab Work	Students are given a bag with a mixture in it. Most of the laboratory equipment required by students was placed on the teacher's demonstration laboratory bench, unassembled. Students settled down to work on the investigation relatively quickly within their laboratory groups. Researcher observed the three selected students with SLIC Checklist. Students to continue with investigation next period.
Teacher Activity During Lab Work	Teacher circulating around the room helping students as necessary, but primarily observing the activities and behavior of students.
Note Taking and Demonstration (Period 2)	Teacher provides students with notes on mixture separation techniques. Writes definitions

TABLE 18 (Cont'd.)

Topic	Summary of Researcher Notations
Note Taking and Demonstration Cont'd.	and examples on the board for decantation and sublimation. Teacher does a demonstration by heating iodine crystals to illustrate sublimation. The cooled container of sublimed iodine crystals were passed around the room for students to observe.
Lab Work	Students continued to work on separating and identifying the components of the mixture. Researcher continued to observe selected students with SLIC checklist. Students appeared to work extremely well on performing this investigation.
Lab Work (Period 3)	Students continued working on separating the mixture components. Researcher made further observations of 3 selected students with SLIC checklist.
Lab Work (Period 4)	Students completed performing Investigation 3 during this period.
Preparing of Lab Reports	As students completed separating and identifying the mixture components, they continued preparing their laboratory reports. The teacher assisted students as needed in preparing their reports. Students to complete their reports for homework, to be handed in next period. The researcher interviewed the three selected students as they completed performing their investigation.

APPENDIX H

LABORATORY INVESTIGATIONS OBSERVED

F. GRADE SEVEN LABORATORY INVESTIGATIONS

ARFVEDSON JUNIOR HIGH SCHOOL

INVESTIGATION NUMBER 1

Problem 14-1 What is one kind of food produced by green plants?

Purpose To test for the presence of glucose in a green plant.

Materials
- Benedict's solution
- green onion stops
- test tube holder
- test tube
- glucose test solution
- Bunsen burner

Procedure

A. Before testing green plants for the simple sugar glucose, review Procedure D. Problem 13-2.

1. What color change occurs when blue Benedict's solution is heated in the presence of glucose?

B. Cut four small pieces from the top of a green onion and put them into a test tube. Add enough water to cover the pieces. Add 5 drops of Benedict's solution to the test tube. Bring to a boil, then continue boiling for about 3 min. Remember to keep the test tube pointed away from you and other people.

2. What was the color of the solution inside the test tube before heating?

3. What is the color of the solution inside the test tube after heating?

4. Glucose is the simple sugar produced in green plants by photosynthesis.. Do the cells of the green top of the onion contain glucose?

C. Cut four small pieces of the white part of onion and put them into a test tube. Add water and Benedict's solution and heat as directed in Step B.

5. What was the color of the solution inside the test tube before heating?

6. What is the color of the solution inside the test tube after heating?

7. Do the cells of the white part of the onion contain glucose?

8. If the white part of the onion contained sugar, how do you think it got there?

D. Roots of plants are unable to produce food because they do not contain chlorophyll and are not exposed to light. Because glucose is able to move readily through cell membranes, it is found in all living cells. The cell uses the glucose as food by breaking it down into smaller compounds. This process produces energy.

9. What evidence did you find that shows that glucose is able to pass through cell membranes and move to different parts of the plant?

10. What is the process that involves the movement of materials through cell membranes?

You should now be able to	Test various parts of a green plant for the presence of glucose.
	Relate the presence of glucose to the process of photosynthesis.
	Describe the processes by which glucose is transported from the leaves to other parts of the plant.

Note : Reference - Life Science: A Problem Solving Approach
Carter et al, Ginn (1977) pp. 261-262

ARFVEDSON JUNIOR HIGH SCHOOL

INVESTIGATION 2

Problem 14-2 When do plant leaves contain starch?

Purpose To determine the effect of light on the presence of starch in leaves.

Materials

starch and water mixture
iodine solution
hot plate or hot water bath
beakers, 250 ml (2)
alcohol
forceps
test tubes(4)
plants (2)
sugar solution
petri dish
test tube rack
vegetable oil

Procedure

A. Review the iodine test for starch used in Problem 1 1-1 and 1 3-2. Repeat the test by adding about 5 drops of iodine solution to 2 ml of starch mixture.

1. What color is found with a positive test for starch?

B. To test the effect of iodine on some other liquids, try adding a few drops of iodine solution to samples of the sugar solution, alcohol, water, and vegetable oil, etc.

2. Do these other materials give a positive test for starch?

C. Select a healthy leaf from the plant that has been growing in the light for 24 h.

D. In order to test for starch, the green pigment (chlorophyll) must be removed. Put the leaf in a beaker, cover with about 3 cm of water, and boil. this boiling is necessary to soften the leaf by breaking down the cell walls.

E. Remove the leaf with forceps and put it in a large test tube 1/3 full of alcohol. Warm the test tube in a beaker full of hot water. The water need not be boiling.

Caution: Be sure that you are in a well ventilated area and away from all open flames. Alcohol fumes are highly flammable!

F. Allow the leaf to stay in the alcohol about 5 min. The leaf should be almost white before it is removed.

G. Lay the leaf flat in an open petri dish and cover it with a small amount of iodine solution. After a few minutes, rinse off the leaf with water and examine it for the presence of starch.

3. In your notebook, draw the leaf and shade in the areas that are the golden color of the iodine solution.

4. Is any color other than that of the iodine present?

5. What is this color, if any?

6. The starch molecule is formed when hundreds of smaller molecules of a certain substance are linked together.

   What substance produced by photosynthesis might have been changed to starch in the leaf?

7. Recalling the experiment you did in Problem 13-2 with starch and sugar in the cellophane tubing, why do you think the starch particle is unable to move out of the cells?

H. Select a healthy leaf from the plant that has been growing in the dark for 24 h.

I. Remove the chlorophyll and test for starch as directed in Steps D, E, F, and G.

8. In your notebook, draw the leaf and color the areas that are either yellow -brown or blue-black.

9. Does the absence of light seem to change the amount of starch in a leaf?

10. If starch is unable to get out of living cells, in what way might this be useful to the plant?

11. What smaller molecules, used to make the giant starch molecule can be used for food by the plant grown in the dark?

12. Because plants grown in the dark lack glucose, the starch was broken down and is used to produce energy. What factor tested in this experiment must be present in order for a green plant to carry out food-making activity?

You should now be able to	Test for the presence of starch with iodine solution. Relate production of starch to exposure to light. Predict whether glucose is being produced as indicated by the presence of starch. Relate light to the process of photosynthesis.

Note: Reference - Life Science: A Problem Solving Approach, Carter et al, Ginn (1977) pp. 264-266

ARFVEDSON JUNIOR HIGH SCHOOL

INVESTIGATION 3

PART C: Internal Structure of a Leaf

Background Information:

Leaf Tissues

You have located the upper and lower epidermis, the stomates and the guard cells of leaves. You may have seen various other kinds of cells in your microscopic examination of the different leaves.

In PART C you will continue your examination of leaf tissues. This time you will study cross sections of several different leaves.

Sections cut at right angles to the length of an object are called cross-sections. The slice of onion put in a hamburger sandwich is a cross section of the onion. This slice would be much too thick to examine under the microscope. You will learn a technique for making a thin cross section of a leaf. Do not be discouraged if it requires several trials before you're able to cut a very thin cross section.

What you will see in the leaf cross section is:

1. Cuticle: Waxy layer on the surface of a leaf which protects the inner cells of the leaf.

2. Upper epidermis: Rectangular layer of cells found below the cuticle containing few stomates. It also protects the inner cells and regulates the flow of water and gas through the leaf.

3. Mesophyll: These are the cells found between the upper and lower epidermis and are arranged in two layers. They are the main food making cells of the leaf.

    a. Palisade cells: The mesophyll cells just below the upper epidermis are regular, oblong cells containing chlorophyll that are stacked compactly at right angles to the surface. The palisade layer may contain one or more rows of cells. Their function is to produce food for the plant.

b. Spongy cells: Between the palisade layer and the lower epidermis the mesophyll cells are loosely packed and more irregular in shape. Between these loosely packed cells arelarger air spaces. These mesophyll cells are called spongy cells.

The spaces between the spongy cells permit the air that enters through the the stomates to circulate through the leaf. These cells contain chlorophyll and therefore produce food for the plant.

4. Vascular tissue: These are the veins that you see in a leaf. This is the conducting and supporting tissue in the leaf which is arranged in bundles of cells.

a. Xylem: These are the thick walled larger-diameter tube cells found on the outside of the vascular bundle. xylem cells conduct water and minerals to the leaf from the roots. They also provide support for the plant.

b. Phloem: These smaller cells of the vascular bundles are found in the centre of the bundle. Phloem cells carry food manufactured by photosynthesis to other parts of the plant for storage and use.

As you examine the cells and tissues in different kinds of leaves, try to relate the structure and arrangement of the cells in the tissue to their function in the leaf. Also try to relate the structures found in a particular leaf to the environment from which the leaf came.

Below is a method for obtaining a thin cross section of a leaf. Read the instructions but do NOT perform the experiment. Instead, obtain a slide of a prepared leaf cross-section from your instructor and observe under low and medium power. Answer the questions starting in section 6.

DESIGN AND OBSERVATIONS :

Materials

- -microscope
- -light source
- -slides
- -cover slip
- -razor blade, new, single-edged
- -leaves, freshly picked
- -medicine dropper
- -tweezers.

1. Prepare a thin cross section of a leaf as follows. Place the leaf to be used between two glass slides in a sandwich form. Use the edges of the glass slides to guide the razor blade as you cut the thinnest slice possible from the edge of a leaf. The proper technique is demonstrated in the diagram below. (Diagram omitted here.)

2. Obtain one thin cross section of the leaf after you have made several sample cuts. Place the cut edge of the section down on the surface of the slide. Be careful not to fold the thin section. Add a drop of water and a cover slip.

3. Observe the slide with both low-power and high-power magnification. Be sure to move the slide to find the thinnest sections for your observations. If the section is dark and the cells are hard to identify, prepare another slide.

4. Prepare a drawing to show the location and general shape of the various cells found inside the leaf.

5. The following diagram of a "Cross section of a leaf" should assist you in locating the parts in a leaf once you have prepared a microscopic slide, of the cells and tissues found inside a leaf, in the manner as described in the design below. (Diagram omitted here.)

6. Label the parts of a leaf structure in your diagram as you answer the following questions:

   a) Describe the shape of the upper and lower epidermal cells.

   ____

   b) Do these cells contain any green chloroplasts?

   ____

   c) Locate the layer of cells that is perpendicular (at right angles) to the upper epidermis. Name the cells. Do they contain chlorophyll?

   ____

   d) Locate the irregularly shaped cells below the palisade cells. Do these cells form a solid layer as you found in the palisade layer?

e) Locate a group of thick-walled cells arranged in a circular pattern. Name these cells.

Inferences:

1. What purpose is served by chlorophyll in plants?

2. Which parts of the plant contain chlorophyll?

3. a) What are the tiny green bodies in leaves called?

   b) What is found in them?

4. What is the purpose of the following cells:

   a) Xylem

   b) Phloem

New Problems:

1. Why is it that the leaves of some plants are much darker green than other plants?

Note: Reference - C.R.I.B., I.B1, I.S.1 (Part C)

GRADE EIGHT INVESTIGATIONS

CHADWICK JUNIOR HIGH SCHOOL

INVESTIGATION 1

Worksheet In Preparation for Investigation 1

Relative Density Problems

1. A mineral has a mass of 40g in air and 36g in water. What is the relative density?

2. A mineral loses 8g in water weighs 93g in air. What is the relative density?

3. If a mineral weighs 284g in water and weighs 12g more in air, what is its relative density?

4. A mineral displaces 15g of water. It weighs 300g in air. What is its relative density?

5. What volume of water is displaced by a rock that weighs 25g in air and 22.5g in water?

6. What is the relative density of a mineral that displaces 14ml of water and weighs 203.5g in water?

7. What is the weight loss of a mineral that displaces 8ml of water.

Investigation 1

Relative Density

Problem:

Is relative density a reliable property to use when identifying a mineral?

Background Information

The formula for relative density (R.D.) is:

$$\text{R.D.} = \frac{\text{mass of mineral in air}}{\text{apparent mass loss}}$$

apparent mass loss = mass of mineral in air - apparent mass of mineral in water

Materials:

Triple beam balance, support stand, string, 800 ml beaker half filled with water, minerals with numbers 26, 3, 25.

Method:

A. 1. Attach your triple beam balance to the retort stand.
2. Attach the string to the lever under the pan of your balance.
3. Adjust the balance until the pointer is at zero by turning the balance knob.
4. Attach your first mineral sample to the end of the string.
5. Find its mass, and record.
6. Now place the beaker of water under the balance and gently lower your mineral sample into it (adjust until the sample is submerged but not touching the bottom).
7. Record, sample mass in water. Exchange your mineral sample with two other groups.
8. Repeat steps 4-8 using your second mineral sample, third, etc.

DATA & OBSERVATIONS

Mineral Number	Trial #	Mass in Air	Mass in Water	Apparent Mass Loss
26	1			
	2			
	3			
3	1			
	2			
	3			

25	1	
	2	
	3	

Inferences: Write a short paragraph of what you found.

Calculations:

Sample	Trial Number	Apparent mass loss (mass of mineral - apparent mass in water)	R.D.= $\frac{\text{mass in air}}{\text{apparent mass loss}}$
26.	1.		
	2.		
	3.		
3.	1.		
	2.		
	3.		
25.	1.		
	2.		
	3.		

Interpretation Questions

1. What is the meaning of relative density?

2. A certain mineral has a relative density of 6.2. What would the relative density be if it were broken exactly in half?

Note: Cross Reference C.R.I.B., 111, A1, 1.S.6, Edmonton Public School Board.

CHADWICK JUNIOR HIGH SCHOOL

INVESITGATION 2

Identification of Minerals

Problem:

To identify the minerals we have been using.

Materials

Activities three to eight

Method:

1. Fill in the data chart with information from the previous activities.
2. Use the mineral reference charts to predict what the mineral sample might be.

Observations:

(Fill in Chart)

Conclusions:

1. List the five tests you have been using to identify minerals:
   ____
   ____
   ____
2. a) Which of these are most accurate? ____________
   b) Why? ______________________________
   ____
3. a) Which of these are least accurate? ____________
   b) Why? ______________________________
   ____

DATA SUMMARY CHART

SAMPLE #	COLOR	LUSTER	STREAK	HARDNESS	RELATIVE DENSITY	NAME OF SAMPLE
3						
26						
18						
14						
2						
10						
27						
29						
6						
24						
28						

Note: Cross Reference C.R.I.B., 111, A1, 1.S.9, Edmonton Public School Board

GRADE NINE INVESTIGATIONS

ASTON JUNIOR HIGH SCHOOL

INVESTIGATION 1

(Including answers)

CONCEPT

A1. Matter is composed of pure substances and mixtures.

PROBLEM

How may elements be distinguished by flame tests?

BACKGROUND INFORMATION

There are certain metallic elements which can be identified by the color they give to a flame. We imagine the atom with a dense nucleus and electrons forming a sort of "charged cloud" around it. When electrons in the outer shells of atoms are sufficiently "excited" by absorbing energy from a suitable source, (such as the energy given off by a hot bunsen burner flame), the electrons are elevated to a higher energy level. The jump to higher energy levels is only momentary. The added heat energy is not enough to keep the electrons at the higher frequency. They immediately lose energy and return to their normal wave length or energy level. As the electrons fall back to their normal wave length or energy levels in the atoms, the energy which they absorbed from the bunsen flame is emitted in the form of light producing a characteristic spectrum or color pattern of that particular element. No two elements have the same spectrum.

Some elements are easy to distinguish by the colors their compounds give when heated in a flame. Many elements are not so easily identified. For such elements we need a way to separate the mixed colors so that we can detect slight differences in color that the eye cannot detect. To do this a spectroscope may be used. Another method to aid in distinguishing colors is to use cobalt glass which filters certain colors associated with impurities.

DESIGN

Materials - bunsen burner
platinum or nichrome wires
cobalt glass square
solutions of various compounds (copper, lithium, calcium, potassium, sodium, barium and strontium)

solid samples of the above compounds

PROCEDURE

1. Look at the solid compounds and their solutions on the demonstration table. Note any similarities or differences and record these in the observation section below.

2. Set up a bunsen burner and adjust to a blue flame.

3. Hold the platinum or nichrome wire loop in the flame until the flame has no color other than its normal blue. Why would it be necessary to do this?

4. Dip the wire into a solution of one of the compounds and then hold the wire in the burner flame. When you test a potassium compound, look at the flame through a cobalt glass square. Record the color of the flame in the data chart below.

5. Repeat step 4 until you have used all the given compounds.

OBSERVATIONS (with answers, students did not have the answers)

1. What are some of the similarities among the solid compounds and their solutions?

2. What are some of the differences?

Name of Element or Compound	Color of Flame
A. barium	pale green (yellow-green)
B. calcium	orange-red
C. copper	emerald green
D. lithium	crimson (deep red color)
E. potassium	violet
F. sodium	yellow
G. strontium	red (scarlet) brilliant red

INFERENCES

1. Can you tell which element is present by looking at its

compound in solution? No, many compounds have the same color.

2. Do copper chloride and sodium chloride give the same color flame? If not which element produces the color? Copper chloride and sodium chloride DO NOT give the same color flame. The sodium and copper produce the color.

3. If you hold a small amount of barium iodide in a flame and obtain a particular colored flame what could you do to be sure that the color is due to the barium and not to iodine? Check the color with that of some pure barium.

4. If you were given an unknown sample of a compound how could you identify one of the elements which make it up? Flame tests.

5. Can pure substances such as elements be distinguished by their properties? Explain. Yes, density, flame test etc. are characteristics of that element.

FURTHER EVIDENCE

How do you explain the fact that if you spill a few drops of soup or milk on a pale-green gas flame when cooking, the flame changes to a mixture of colors with yellow most common? i.e. presence of calcium in milk.

Note: Reference C.R.I.B., V. Al, b , LP-S, IS.2, 1b
Edmonton Public School Board.

ASTON JUNIOR HIGH SCHOOL

INVESTIGATION 2

V. Composition of Matter.

CONCEPT

A1. Matter is composed of pure substances and mixtures.

PROBLEM

How may one distinguish between a mixture and a compound (pure substance)?

BACKGROUND INFORMATION

Mixtures and Compounds

Study the following definitions carefully before proceeding:

ELEMENT: An element is a substance that contains only one kind of atom?

COMPOUND: A compound consists of two or more elements held together chemically. A compound has properties which are usually different from those of its components, and are difficult to separate.

MIXTURE A mixture is an association of two or more materials which retain their identity. A mixture may contain solids, liquids, gases, or any combination of these phases. Many mixtures are essential to life, such as blood, and many mixtures are used in day-to-day living. A mixture can be separated into its parts by simple mechanical means.

When two elements are mixed together at room temperature, they usually do not combine chemically to form a compound--that is, a substance with a new set of properties. It is more likely that the different kinds of particles mix together to produce a mixture. Mixtures retain some of the original properties of the elements that compose them.

One way of telling whether a mixture has been formed rather than a compound is to try to recover the original materials. If the original materials can be separated by physical processes (mechanical means), such as, dissolving (solubility) or magnetic attraction, the product is not a compound. If the product cannot be physically separated into its original components, and if it retains a new set of properties, it is probably a compound. In the experiment that follows you will learn how to test a material to see if it is a mixture or a compound.

DESIGN

Materials - iron filings
roll sulfur (powder)
test tubes (2)
magnet
bunsen burner
test tube holder
hammer
paper towel
small plastic bags (3)

1. Obtain a small quantity of iron filings and powdered sulfur. Examine and record the appearance of each element in the data chart below. (Chart A)

2. Place a small quantity of iron filings into a small, clean, dry test tube. Hold a magnet against the test tube near the iron filings, move it up and down, observe and record the results in Chart A.

3. Repeat step 2 with sulfur instead of iron filings. Record observations in Chart A.

4. Fill both test tubes half full of water. Try to dissolve both the iron and the sulfur by shaking the test tubes. Record your observations on their solubility in Chart A.

5. Add powdered sulfur to a small clean dry test tube to a depth of 2 cm. To the same test tube add (0.5 cm) of iron filings. Mix thoroughly and describe the appearance of the resulting mixture. Record your observations in Chart B.

6. Place a small quantity of the mixture on an open paper towel. To determine if this mixture of iron and sulfur is attracted by a magnet, place the magnet in a small plastic bag and touch the material on the paper towel. Record your observations in Chart B.

7. Heat the mixture over a bunsen burner flame. Hold the test tube at an angle to the flame and pointing away from yourself or anyone else. Heat until it glows bright red and continue heating for two more minutes.

8. Allow the test tube and its contents to cool. After it has cooled remove the contents. It may be necessary to break the test tube. To do this wrap the test tube in a paper towel and tap it with a hammer. Observe and describe the appearance of this material. Record your observations in Chart B.

9. Test this substance from the test tube with a magnet. Record observations.

OBSERVATIONS AND ORGANIZATION OF DATA

A.

Element	Appearance	Solubility	Attracted by Magnet
iron			
sulfur			

B.

Elements Combined	Appearance	Attracted by Magnet
Material before heating		
Material after heating		

INFERENCES

1. Would water be useful for separating a mixture of sulfur and iron? Explain.

2. Carbon disulfide is a flammable and poisonous liquid which should not be used in schools. However it can dissolve sulfur. Explain how you could use carbon disulfide to separate a mixture of iron and sulfur.

3. How could you use a magnet to separate a mixture of iron and sulfur?

4. Can the combination of iron and sulfur truly be called a mixture? Support your answer using evidence from the experiment.

5. Is the material after heating attracted to the magnet? Does the iron separate from the sulfur? What does this show?

6. If this material after heating were added to carbon disulfide it would not dissolve at all. How is this material different from the original mixture of sulfur and iron?

7. Is this new material a mixture or a pure substance? Explain.

8. How can one distinguish between a mixture and a pure substance (compound)?

OPERATIONAL DEFINITIONS

Write an operational definition of:

i. mixture

ii. compound

NEW PROBLEM

Obtain a labelled unknown sample from your teacher and identify it as either a mixture or a pure substance.

Note: Reference C.R.I.B., V, A1, abc, LP-S, IS-3, 2b
Edmonton Public School Board

ASTON JUNIOR HIGH SCHOOL

INVESTIGATION 3

An Openended Investigation in Which Students Need to Make Use of the Information Learned in Investigations Completed on Composition of Matter.

Background Information (previously performed C.R.I.B. investigations)

1. How may elements be distinguished by flame tests?
2. How may one distinguish between a mixture and a compound (pure substance)?
3. To define the characteristics of solutions, dispersion and suspension.
4. Separation into component parts by diffusion.
5. How to obtain the original substance from a mixture by distillation.
6. To study a soda pop separation (by freezing).

Problem

To separate and identify as many components as possible from the mixture.

Procedure

- Students given an unknown mixture which they are to separate and identify. (All students given same mixture of iron filings, sulfur, sugar, plastic beads and sand).
- Students to work in their lab groups, but each student needs to prepare his/her own lab report, which is to be handed in for marking by the teacher.

APPENDIX I

ANALYSIS OF INVESTIGATIONS FOR SCIENTIFIC PROCESS SKILLS

TABLE 19

ANALYSIS OF GRADE SEVEN INVESTIGATIONS

ARFVEDSON JUNIOR HIGH SCHOOL

INVESTIGATION 1

WHAT IS ONE KIND OF FOOD PRODUCED BY GREEN PLANTS?

Legend: S = student initiated
T = teacher guidance provided
N = guidance provided by laboratory notes

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
1. IDENTIFYING AND FORMULATING A PROBLEM		
(a) speculating	N	
(b) identifying variables	N	-teacher helps to establish focus for the problem
(c) making assumptions	N	
(d) delimiting problem	N,T	
2. SEEKING BACKGROUND INFORMATION		
(a) recalling experiences	N,T	-teacher provides students with extra notes
(b) doing literature research	N	
(c) consulting people		
3. PREDICTING		
4. HYPOTHESIZING		

TABLE 19 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
5. DESIGNING COLLECTION OF DATA		-teacher changing type of clamp used -teacher idicating precautions during pre-lab -teacher put chart for recording data on chalkboard
(a) defining variables	N	
(b) developing experimental steps	N	
(c) needed equipment and techniques	N,T	
(d) safety precautions	N,T	
(e) method of recording data	T	
6. PROCEDURE		-students obtained required equipment from side counter and under counter of lab tables and assembled equipment as necessary
(a) collecting and setting up apparatus	S	
(b) performing experiment	S	
(c) modifying procedure		
(d) repeating experiment		
(e) recording data	S	
7. OBSERVING AND OBSERVATIONS		
(a) qualitative data	S	
(b) quantitative data		
(c) gathering specimens		
(d) obtaining graphical data		
(e) noting unexpected occurences		
(f) noting accuracy of data		
(g) judging reliability and validity of data		
8. ORGANIZING THE DATA		
(a) ordering		
(b) classifying		
(c) comparing	S	

TABLE 19 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
9. REPRESENTING THE DATA GRAPHICALLY		
(a) drawing graphs, diagrams, etc.		
(b) interpolating and extrapolating		
10. TREATING DATA MATHEMATICALLY		
(a) calculating		
(b) using statistics		
(c) uncertainity of results		
11. INTERPRETING THE DATA		
(a) explanation of data	N,S	-notes provide students with questions that they answer by interpreting their collected data
(b) deriving inferences	N,S	
(c) assessing validity of predictions		
12. FORMULATING OPERATIONAL DEFINITIONS		
(a) verbal		
(b) mathematical		
13. EXPRESSING DATA IN THE FORM OF A MATHEMATICAL RELATIONSHIP		
14. INCORPORATING THE NEW DISCOVERY INTO THE EXISTING THEORY		
15. SEEKING FURTHER EVIDENCE TO:		
(a) increase confidence		
(b) test generalizability		

TABLE 19. (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
16. IDENTIFYING NEW PROBLEMS FOR INVESTIGATION BECAUSE OF: (a) effect of new variables (b) unexpected observations (c) inconsistencies in theory		
17. APPLYING THE DISCOVERED KNOWLEDGE	N,T	-notes provide applications in background to experiment, and teacher also gives applications during post-lab discussions.
TOTAL NUMBER OF SUBSKILL INITIATIONS	26	
NUMBER OF STUDENT SUBSKILL INITIATIONS	7	
% OF SCIENTIFIC SKILLS USED REQUIRING STUDENT INVOLVEMENT = $\frac{7}{26} \times 100\% = 27\%$		-fair level of inquiry

TABLE 20

ANALYSIS OF GRADE SEVEN INVESTIGATIONS

INVESTIGATION 2

WHEN DO PLANT LEAVES CONTAIN STARCH?

Legend: S = student initiated
T = teacher guidance provided
N = guidance provided by laboratory notes

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
1. IDENTIFYING AND FORMULATING A PROBLEM		
(a) speculating	N	-teacher assists by focussing in on the problem
(b) identifying variables	N	
(c) making assumptions	N	
(d) delimiting problem	N,T	
2. SEEKING BACKGROUND INFORMATION		
(a) recalling experiences	N	-teacher provides additional background notes
(b) doing literature research	N,T	
(c) consulting people		
3. PREDICTING		
4. HYPOTHESIZING		

TABLE 20 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
5. DESIGNING COLLECTION OF DATA		
(a) defining variables	N	
(b) developing experimental steps	N	-teacher modified list of equipment, use of bunsen burner
(c) needed equipment and techniques	N,T	
(d) safety precautions	T,N	-teacher outlines safety precautions in pre-lab discussion
(e) method of recording data		
6. PROCEDURE		
(a) collecting and setting up apparatus	S	-teacher sets out required equipment on side counter and students collect it and assemble as required
(b) performing experiment	S	
(c) modifying procedure		
(d) repeating experiment		
(e) recording data	S	
7. OBSERVING AND OBSERVATIONS		
(a) qualitative data	S	
(b) quantitative data		
(c) gathering specimens	T	-teacher provided plants, those kept in light and those kept in the dark
(d) obtaining graphical data		
(e) noting unexpected occurrences		
(f) noting accuracy of data		
(g) judging reliability and validity of data		
8. ORGANIZING THE DATA		
(a) ordering		-students had to compare data collected for plant in light with that collected for plant in dark
(b) classifying		
(c) comparing	S	

TABLE 20 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
9. REPRESENTING THE DATA GRAPHICALLY		
(a) drawing graphs, diagrams, etc.	S	-students required to draw diagrams in their note books of the leaves used
(b) interpolating and extrapolating		
10. TREATING DATA MATHEMATICALLY		
(a) calculating		
(b) using statistics		
(c) uncertainty of results		
11. INTERPRETING THE DATA		
(a) explanation of data	N,S	-book asked students questions requiring explanations and deriving of inferences
(b) deriving inferences	N,S	
(c) assessing validity of predictions		
12. FORMULATING OPERATIONAL DEFINITIONS		
(a) verbal		
(b) mathematical		
13. EXPRESSING DATA IN THE FORM OF A MATHEMATICAL RELATIONSHIP		
14. INCORPORATING THE NEW DISCOVERY INTO THE EXISTING THEORY		
15. SEEKING FURTHER EVIDENCE TO:		
(a) increase confidence		
(b) test generalizability		

TABLE 20 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
16. IDENTIFYING NEW PROBLEMS FOR INVESTIGATION BECAUSE OF: (a) effect of new variables (b) unexpected observations (c) inconsistencies in theory		
17. APPLYING THE DISCOVERED KNOWLEDGE	N	-background provided in book related possible applications
TOTAL NUMBER OF SUBSKILL INITIATIONS	26	
NUMBER OF STUDENT SUBSKILL INITIATIONS	8	
% OF SCIENTIFIC SKILLS USED REQUIRING STUDENT INVOLVEMENT = $\frac{8}{26}$ X 100% = 31%		-fair level of inquiry

TABLE 21

ANALYSIS OF GRADE SEVEN INVESTIGATIONS

INVESTIGATION 3

INTERNAL STRUCTURE OF A LEAF

Legend; S = student initiated
T = teacher guidance provided
N = guidance provided by laboratory notes

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
1. IDENTIFYING AND FORMULATING A PROBLEM		
(a) speculating	N	-teacher assisted students to focus in and understand the problem
(b) identifying variables	N	
(c) making assumptions		
(d) delimiting problem	N,T	
2. SEEKING BACKGROUND INFORMATION		
(a) recalling experiences	N,T	-teacher reviewing with the class
(b) doing literature research		
(c) consulting people		
3. PREDICTING		
4. HYPOTHESIZING		

TABLE 21 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
5. DESIGNING COLLECTION OF DATA		
(a) defining variables		
(b) developing experimental steps	N	
(c) needed equipment and techniques	N	-teacher points out safety precautions in pre-lab discussions
(d) safety precautions	N,T	
(e) method of recording data	N	
6. PROCEDURE		
(a) collecting and setting up apparatus	S,T	-teacher sets out some of the materials and equipment on side counter
(b) performing experiment	S	-students had to answer observation questions in notes provided
(c) modifying procedure		
(d) repeating experiment		
(e) recording data	S	
7. OBSERVING AND OBSERVATIONS		
(a) qualitative data	S	
(b) quantitative data		
(c) gathering specimens		
(d) obtaining graphical data		
(e) noting unexpected occurrences		
(f) noting accuracy of data		
8. ORGANIZING THE DATA		
(a) ordering		-students comparing their slide observations with the diagram of leaf structure provided in notes
(b) classifying		
(c) comparing	S	

TABLE 21 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
9. REPRESENTING THE DATA GRAPHICALLY		
(a) drawing graphs, diagrams, etc.	S	
(b) interpolating and extrapolating		
10. TREATING DATA MATHEMATICALLY		
(a) calculating		
(b) using statistics		
(c) uncertainty of results		
11. INTERPRETING THE DATA		
(a) explanation of data	N,S	-students had to answer a series of inference questions
(b) deriving inferences	N,S	
(c) assessing validity of predictions		
12. FORMULATING OPERATIONAL DEFINITIONS		
(a) verbal		
(b) mathematical		
13. EXPRESSING DATA IN THE FORM OF A MATHEMATICAL RELATIONSHIP		
14. INCORPORATING THE NEW DISCOVERY INTO THE EXISTING THEORY		
15. SEEKING FURTHER EVIDENCE TO:		
(a) increase confidence		
(b) test generalizability		

TABLE 21 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
16. IDENTIFYING NEW PROBLEMS FOR INVESTIGATION BECAUSE OF: (a) effect of new variables (b) unexpected observations (c) inconsistencies in theory	N,S	-notes state a new problem question for students to answer
17. APPLYING THE DISCOVERED KNOWLEDGE		
TOTAL NUMBER OF SUBSKILL INITIATIONS	24	
NUMBER OF STUDENT SUBSKILL INITIATIONS	9	
% OF SCIENTIFIC SKILLS REQUIRING STUDENT INVOLVEMENT = $\frac{9}{24} \times 100\% = 38$		-fair level of inquiry

TABLE 22

ANALYSIS OF GRADE EIGHT INVESTIGATION

CHADWICK JUNIOR HIGH SCHOOL

INVESTIGATION 1

RELATIVE DENSITY

Legend: S = student initiated
T = teacher guidance provided
N = guidance provided by laboratory notes

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
1. IDENTIFYING AND FORMULATING A PROBLEM		
(a) speculating	N	-problem is initially given in lab notes. Students modify the problem slightly by putting it in their own words within lab report
(b) identifying variables	N,T	
(c) making assumptions	N	
(d) delimiting problem	T,N,S	
2. SEEKING BACKGROUND INFORMATION		
(a) recalling experiences	N,T	-much of the background information is related by the teacher during pre-lab discussion
(b) doing literature research	N,T	
(c) consulting people		
3. PREDICTING		
4. HYPOTHESIZING	S	

TABLE 22 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
5. DESIGNING COLLECTION OF DATA		-procedure outlined by notes and modified by teachers as deemed necessary. Students make the charts for recording data with the teacher's guidance
(a) defining variables	S	
(b) developing experimental steps	N,T	
(c) needed equipment and techniques	N,T	
(d) safety precautions	S,T	
(e) method of recording data	S,T	
6. PROCEDURE		-students do three trials with each mineral to determine relative density
(a) collecting and setting up apparatus	S	
(b) performing experiment	S	
(c) modifying procedure		
(d) repeating experiment	S	
(e) recording data	S	
7. OBSERVING AND OBSERVATIONS		-students gather their own mineral samples from a supply on side counter
(a) qualitative data		
(b) quantitative data	S	
(c) gathering specimens	S	
(d) obtaining graphical data		
(e) noting unexpected occurrences		
(f) noting accuracy of data		
(g) judging reliability and validity of data	S	
8. ORGANIZING THE DATA		
(a) ordering	S	
(b) classifying		
(c) comparing		

TABLE 22 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
9. REPRESENTING THE DATA GRAPHICALLY		
(a) drawing graphs, diagrams, etc.	S	-students put data in two different charts
(b) interpolating and extrapolating		
10. TREATING DATA MATHEMATICALLY		
(a) calculating	S	-finding of relative density
(b) using statistics		
(c) uncertainty of results		
11. INTERPRETING THE DATA		
(a) explanation of data		-students make their own inferences and develop answers to inference questions
(b) deriving inferences	S	
(c) assessing validity of predictions	S	
12. FORMULATING OPERATIONAL DEFINITIONS		
(a) verbal	S	
(b) mathematical	N,T	
13. EXPRESSING DATA IN THE FORM OF A MATHEMATICAL RELATIONSHIP	N,T	-lab notes and teacher provide needed mathematical relationships
14. INCORPORATING THE NEW DISCOVERY INTO THE EXISTING THEORY		
15. SEEKING FURTHER EVIDENCE TO:		
(a) increase confidence		
(b) test generalizability		

TABLE 22 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
16. IDENTIFYING NEW PROBLEMS FOR INVESTIGATION BECAUSE OF: (a) effect of new variables (b) unexpected observations (c) inconsistencies in theory		
17. APPLYING THE DISCOVERED KNOWLEDGE	S	
TOTAL NUMBER OF SUBSKILL INITIATIONS	39	
NUMBER OF STUDENT SUBSKILL INITIATIONS	19	
% OF SCIENTIFIC SKILLS USED REQUIRING STUDENT INVOLVEMENT = $\frac{19}{39}$ x 100% = 49%		-moderate level of inquiry

TABLE 23

ANALYSIS OF GRADE EIGHT INVESTIGATIONS

INVESTIGATION 2

IDENTIFICATION OF MINERALS

Legend: S = student initiated
T = teacher guidance provided
N = guidance provided by laboratory notes

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
1. IDENTIFYING AND FORMULATING A PROBLEM		
(a) speculating	N	
(b) identifying variables	N	
(c) making assumptions	N	
(d) delimiting problem	N,T	
2. SEEKING BACKGROUND INFORMATION		
(a) recalling experiences	T,S	-students to recall relevant knowledge and experiences from previous investigations
(b) doing literature research		
(c) consulting people		
3. PREDICTING		
4. HYPOTHESIZING		

TABLE 23 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
5. DESIGNING COLLECTION OF DATA		
(a) defining variables		
(b) developing experimental steps	N,T	
(c) needed equipment and techniques	N	
(d) safety precautions		
(e) method of recording data		
6. PROCEDURE		
(a) collecting and setting up apparatus	S	
(b) performing experiment	S	
(c) modifying procedure		
(d) repeating experiment		
(e) recording data	S	
7. OBSERVING AND OBSERVATIONS		
(a) qualitative data		
(b) quantitative data	S	
(c) gathering specimens		
(d) obtaining graphical data		
(e) noting unexpected occurrences		
(f) noting accuracy of data		
(g) judging reliability and validity of data		
8. ORGANIZING THE DATA		
(a) ordering	N	-students need to compare information provided by the various identification tests
(b) classifying		
(c) comparing	S	

TABLE 23 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
9. REPRESENTING THE DATA GRAPHICALLY		
(a) drawing graphs, diagrams, etc.		
(b) interpolating and extrapolating		
10. TREATING DATA MATHEMATICALLY		
(a) calculating	S	-calculating of relative density for each mineral
(b) using statistics		
(c) uncertainty of results		
11. INTERPRETING THE DATA		
(a) explanation of data		-lab notes guide students to make inferences by asking of questions (however these interpretation questions are relatively open-ended)
(b) deriving inferences	N,S	
(c) assessing validity of predictions		
12. FORMULATING OPERATIONAL DEFINITIONS		
(a) verbal		
(b) mathematical		
13. EXPRESSING DATA IN THE FORM OF A MATHEMATICAL RELATIONSHIP		
14. INCORPORATING THE NEW DISCOVERY INTO THE EXISTING THEORY		
15. SEEKING FORMER EVIDENCE TO:		
(a) increase confidence		-students check applicability of identification tests for identifying a mineral
(b) test generalizability	S	

TABLE 23 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
16. IDENTIFYING NEW PROBLEMS FOR INVESTIGATION BECAUSE OF: (a) effect of new variables (b) unexpected observations (c) inconsistencies in theory		
17. APPLYING THE DISCOVERED KNOWLEDGE	S	-students use data obtained to identify the mineral by use of a mineral reference chart
TOTAL NUMBER OF SUBSKILL INITIATIONS	21	
NUMBER OF STUDENT SUBSKILL INITIATIONS	10	
% OF SCIENTIFIC SKILLS USED REQUIRING STUDENT INVOLVEMENT = $\frac{10}{21} \times 100\% = 48\%$		-moderate level of inquiry

TABLE 24

ANALYSIS OF GRADE NINE INVESTIGATIONS

ASTON JUNIOR HIGH SCHOOL

INVESTIGATION 1

HOW MAY ELEMENTS BE DISTINGUISHED BY FLAME TESTS?

Legend: S = student initiated
T = teacher guidance provided
N = guidance provided by laboratory notes

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
1. IDENTIFYING AND FORMULATING A PROBLEM		
(a) speculating	N	-lab notes outline the problem, and background information
(b) identifying variables	N	
(c) making assumptions	N	
(d) delimiting problem	N,T	
2. SEEKING BACKGROUND INFORMATION		
(a) recalling experiences	N,T	-teacher reviews during pre-lab discussion and then provides additional background information
(b) doing literature research	N	
(c) consulting people		
3. PREDICTING		
4. HYPOTHESIZING		

TABLE 24 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
5. DESIGNING COLLECTION OF DATA		
(a) defining variables		lab notes list the materials, and steps to be followed in performing the experiment
(b) developing experimental steps	N	
(c) needed equipment and techniques	N,T	
(d) safety precautions	T	-teacher deals with safety precautions during pre-lab discussions, tables are provided in the notes for recording data
(e) method of recording data	N	
6. PROCEDURE		
(a) collecting and setting up apparatus	S	-students set up the apparatus after it has been placed on the lab table (or demonstration table) by the teacher
(b) performing experiment	S	
(c) modifying procedure		
(d) repeating experiment		
(e) recording data		
7. OBSERVING AND OBSERVATIONS		
(a) qualitative data	S	
(b) quantitative data		
(c) gathering specimens	T	-students note flame color -teacher develops or prepares needed solutions
(d) obtaining graphical data		
(e) noting unexpected occurrences		
(f) noting accuracy of data		
(g) judging reliability and validity of data		
8. ORGANIZING THE DATA		
(a) ordering	N	-data organized in chart by the lab notes
(b) classifying		
(c) comparing		

TABLE 24 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
9. REPRESENTING THE DATA GRAPHICALLY		
(a) drawing graphs, diagrams, etc.		
(b) interpolating and extrapolating		
10. TREATING DATA MATHEMATICALLY		
(a) calculating		
(b) using statistics		
(c) uncertainty of results		
11. INTERPRETING THE DATA		
(a) explanation of data	S	-students need to examine data to answer
(b) deriving inferences	S	a series of prepared inference questions
(c) assessing validity of predictions		
12. FORMULATING OPERATIONAL DEFINITIONS		
(a) verbal		
(b) mathematical		
13. EXPRESSING DATA IN THE FORM OF A MATHEMATICAL RELATIONSHIP		
14. INCORPORATING THE NEW DISCOVERY INTO THE EXISTING THEORY		
15. SEEKING FURTHER EVIDENCE TO:		
(a) increase confidence		-students asked to answer or explain
(b) test generalizability	S	a further evidence question

TABLE 24 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
16. IDENTIFYING NEW PROBLEMS FOR INVESTIGATION BECAUSE OF: (a) effect of new variables (b) unexpected observations (c) inconsistencies in theory		
17. APPLYING THE DISCOVERED KNOWLEDGE		
TOTAL NUMBER OF SUBSKILL INITIATIONS	21	
NUMBER OF STUDENT SUBSKILL INITIATIONS	6	
% OF SCIENTIFIC SKILLS REQUIRING STUDENT INVOLVEMENT = $\frac{6}{21}$ X 100% = 29%		-fair level of inquiry

TABLE 25

ANALYSIS OF GRADE NINE INVESTIGATIONS

INVESTIGATION 2

HOW MAY ONE DISTINGUISH BETWEEN A MIXTURE AND A COMPOUND (PURE SUBSTANCE)?

Legend: S = student initiated
T = teacher guidance provided
N = guidance provided by laboratory notes

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
1. IDENTIFYING AND FORMULATING A PROBLEM		
(a) speculating	N	-lab notes provide the problem
(b) identifying variables	N	
(c) making assumptions	N	
(d) delimiting problem	N,T	
2. SEEKING BACKGROUND INFORMATION		
(a) recalling experiences	N,T	-most of the background is provided by the lab notes with the teacher adding information as needed
(b) doing literature research		
(c) consulting people		
3. PREDICTING		
4. HYPOTHESIZING		

TABLE 25 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
5. DESIGNING COLLECTION OF DATA		
(a) defining variables	N	-needed equipment is identified in the notes, with the teacher helping students to identify the equipment, if students have not been exposed to it previously -the teacher also demonstrates required unfamiliar techniques
(b) developing experimental steps	N	
(c) needed equipment and techniques	N,T	
(d) safety precautions	T	
(e) method of recording data	N	
6. PROCEDURE		
(a) collecting and setting up apparatus	S	
(b) performing experiment	S	
(c) modifying procedure		
(d) repeating experiment		
(e) recording data	S	
7. OBSERVING AND OBSERVATIONS		
(a) qualitative data	S	-teacher prepares/collects the materials and puts them on a table at the front of the class
(b) quantitative data	S	
(c) gathering specimens	T	
(d) obtaining graphical data		
(e) noting unexpected occurrences		
(f) noting accuracy of data		
(g) judging reliability and validity of data		
8. ORGANIZING THE DATA		
(a) ordering	N	-students record all observations in a chart provided in lab notes
(b) classifying		
(c) comparing	S	

TABLE 25 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
9. REPRESENTING THE DATA GRAPHICALLY		
(a) drawing graphs, diagrams, etc.		
(b) interpolating and extrapolating		
10. TREATING DATA MATHEMATICALLY		
(a) calculating		
(b) using statistics		
(c) uncertainty of results		
11. INTERPRETING THE DATA		
(a) explanation of data	S	-students answer the inference questions posed in the lab notes
(b) deriving inferences	S	
(c) assessing validity of predictions		
12. FORMULATING OPERATIONAL DEFINITIONS		
(a) verbal	S	-students required to write operational definitions of mixture and compound
(b) mathematical		
13. EXPRESSING DATA IN THE FORM OF A MATHEMATICAL RELATIONSHIP		
14. INCORPORATING THE NEW DISCOVERY INTO THE EXISTING THEORY		
15. SEEKING FURTHER EVIDENCE TO:		
(a) increase confidence		
(b) test generalizability		

TABLE 25 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
16. IDENTIFYING NEW PROBLEMS FOR INVESTIGATION BECAUSE OF: (a) effect of new variables (b) unexpected observations (c) inconsistencies in theory		
17. APPLYING THE DISCOVERED KNOWLEDGE	S	-students required to identify unknowns using the learned information
TOTAL NUMBER OF SUBSKILL INITIATIONS	25	
NUMBER OF STUDENT SUBSKILL INITIATIONS	10	
% OF SCIENTIFIC SKILLS USED REQUIRING STUDENT INVOLVEMENT = $\frac{10}{25} \times 100\% = 40\%$		-fair level of inquiry

TABLE 26

ANALYSIS OF GRADE NINE INVESTIGATIONS

INVESTIGATION 3

(Openended)

SEPARATION AND IDENTIFICATION OF MIXTURE COMPONENTS

Legend: S = student initiated
T = teacher guidance provided
N = guidance provided by laboratory notes

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
1. IDENTIFYING AND FORMULATING A PROBLEM		
(a) speculating	T	-teacher provided students with a statement of the problem
(b) identifying variables	T	
(c) making assumptions	T	
(d) delimiting problem	T	
2. SEEKING BACKGROUND INFORMATION		
(a) recalling experiences	S,T	-during the pre-lab teacher provided students with notes, students were also required to recall previous separation of mixture techniques
(b) doing literature research		
(c) consulting people		
3. PREDICTING		
4. HYPOTHESIZING	S	

TABLE 26 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
5. DESIGNING COLLECTION OF DATA		
(a) defining variables		
(b) developing experimental steps	S	
(c) needed equipment and techniques	S,T	
(d) safety precautions	T	-teacher indicated some needed precautions during pre-lab discussion
(e) method of recording data	S	
6. PROCEDURE		
(a) collecting and setting up apparatus	S	-students are required to develop their own methods (steps) in separating the components of the mixture from those used in class previously
(b) performing experiment	S	
(c) modifying procedure	S	
(d) repeating experiment	S	
(e) recording data	S	
7. OBSERVING AND OBSERVATIONS		
(a) qualitative data	S	-students provided with the sample mixture needed to separate and identify components
(b) quantitative data		
(c) gathering specimens		
(d) obtaining graphical data		
(e) noting unexpected occurrences	S	
(f) noting accuracy of data		
(g) judging reliability and validity of data		
8. ORGANIZING THE DATA		
(a) ordering	S	
(b) classifying		
(c) comparing		

TABLE 26 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
9. REPRESENTING THE DATA GRAPHICALLY		
(a) drawing graphs, diagrams, etc.	S	-students developed their own charts for recording data
(b) interpolating and extrapolating		
10. TREATING DATA MATHEMATICALLY		
(a) calculating		
(b) using statistics		
(c) uncertainty of results		
11. INTERPRETING THE DATA		
(a) explanation of data		
(b) deriving inferences	S	
(c) assessing validity of predictions	S	
12. FORMULATING OPERATIONAL DEFINITIONS		
(a) verbal		
(b) mathematical		
13. EXPRESSING DATA IN THE FORM OF A MATHEMATICAL RELATIONSHIP		
14. INCORPORATING THE NEW DISCOVERY INTO THE EXISTING THEORY		
15. SEEKING FURTHER EVIDENCE TO:		
(a) increase confidence		
(b) test generalizability		

TABLE 26 (Cont'd)

SCIENTIFIC PROCESS SKILLS	STRUCTURING	COMMENTS
16. IDENTIFYING NEW PROBLEMS FOR INVESTIGATION BECAUSE OF: (a) effect of new variables (b) unexpected observations (c) inconsistencies in theory		
17. APPLYING THE DISCOVERED KNOWLEDGE		
TOTAL NUMBER OF SUBSKILL INITIATIONS	23	
NUMBER OF STUDENT SUBSKILL INITIATIONS	16	
% OF SCIENTIFIC SKILLS REQUIRING STUDENT INVOLVEMENT = $\frac{16}{23}$ x 100% = 70%		-high level of inquiry

APPENDIX J

EDITED LABORATORY REPORTS OF THREE SELECTED STUDENTS

EDITED LABORATORY REPORTS OF THREE SELECTED STUDENTS

ARFVEDSON GRADE 7

INVESTIGATION 1

Legend: (K) = Karl's response
(J) = Jacob's response
(O) = Olaf's response
N.R. = no response

Pre-Laboratory Activity
Read pages 257 to 261 - Life Science, Carter, et al and answer the following questions.

(1) Aristotle believed all the plants' food came from the soil. Who tested this idea? How was it disproved?
(K) Van Helmont
(J) Johannes Van Helmont
(O) Van Helmont. The soil could not account for the growth of the plant.

(2) A plant uses water and carbon dioxide as raw materials for photosynthesis. How does water enter the leaf? How does carbon dioxide enter the leaf?
(K) By osmosis. Through the stomata in the leaves.
(J) Osmosis.
(O) N.R.

(3) Why is light important in photosynthesis?
(K) Without light energy photosynthesis cannot occur.
(J) Because with light it produces sugar.
(O) N.R.

(4) Can photosynthesis be carried on in the dark?
(K) No, light energy is not present in the dark.
(J) No.
(O) No.

(5) What happens to the excess sugar that a plant produces during day?
(K) The sugar is turned into starch which is stored.
(J) It is changed to starch and later on in the night it is changed to glucose again.
(O) It dissolves, they store it.

(6) At night, a plant can only carry on respiration. Look back to the notes given to you on photosynthesis and respiration. What does respiration mean?
(K) Breathing (releasing energy and materials).
(J) Breathing.
(O) N.R.

ARFVEDSON GRADE 7, INVESTIGATION 1 (Cont'd).

When does the plant produce oxygen?
(K) During photosynthesis.
(J) During the day.
(O) N.R.

When does the plant use up oxygen?
(K) During respiration (all the time).
(J) Day and night.
(O) When the sun shines on it.

Investigation 1 - Laboratory Report Responses

Problem
What is one kind of food produced by green plants?

Purpose
To test for the presence of glucose in a green plant.

Background Information
The white and green parts of an onion are tested for the presence of glucose. The onion parts, green and white; were heated in the presence of Benedict's solution and water. A positive test for glucose is indicated by the solution turning orange from a blue color.

Observations
green onion parts and Benedict's solution:
(K) blue to yellow
(J) blue to yellow to orange-red
(O) blue to orange-yellow

white parts of onion and Benedict's solution:
(K) blue to orange
(J) blue to yellow to dark orange
(O) blue to orange

corn syrup and Benedict's solution:
(K) blue to orange
(J) blue to dark orange
(O) blue to orange-yellow

water and Benedict's solution:
(K) blue to light green
(J) blue to light green
(O) blue to light green

Questions
(1) What color change occurs when blue Benedict's solution is heated in the presence of glucose?

ARFVEDSON GRADE 7, INVESTIGATION 1 (Cont'd)

(K) It turns orange from blue.
(J) The blue color of Benedict's solution changes to orange.
(O) It changes to an orange color.

(2) What was the color of the solution inside the test tube before heating?
(K) Before heating water and Benedict's solution is a blue color. (green part of the onion)
(J) The color was blue before heating.
(O) Before heating the solution is blue.

(3) What is the color of the solution inside the test tube after heating?
(K) After heating in the presence of glucose Benedict's solution is an orange color. (green part of onion)
(J) The color is orange.
(O) After heating it is orange.

(4) Glucose is the simple sugar produced in green plants by photosynthesis. Do the cells of the green top of the onion contain glucose?
(K) The cells of a green onion top do contain glucose.
(J) Yes they do.
(O) I think that the green top of the onion does contain glucose.

(5) What was the color of the solution inside the test tube before heating?
(K) Before heating Benedict's solution is blue (white part of onion).
(J) The color of the test tube before heating was blue.
(O) Before heating the solution is blue.

(6) What is the color of the solution inside the test tube after heating?
(K) After heated together with glucose, Benedict's solution is orange (white part of onion).
(J) The color of the test tube after heating is orange.
(O) After heating the solution is orange.

(7) Do the cells of the white part of the onion contain glucose?
(K) The white onion cells do contain glucose.
(J) The white part of the onion cells do have glucose.
(O) I think that all parts of the onion contain glucose.

ARFVEDSON GRADE 7, INVESTIGATION 1 (Cont'd)

(8) If the white part of the onion contained sugar, how do you think it got there?
- (K) Glucose got from the green to the white part of the onion by diffusion.
- (J) The glucose probably got there by diffusion.
- (O) I think glucose travels throughout the whole plant during photosynthesis.

(9) What evidence did you find that shows that glucose is able to pass through cell membranes and move to different parts of the plant?
- (K) The fact that when heated the onion released glucose into the Benedict's solution, it diffused. We have a positive Benedict's test for glucose in the white onion cells and because white onion cells cannot produce glucose, glucose must come from the green part of the onion.
- (J) My evidence of the glucose passing the cell membrane is: we found that the white part has no chloroplasts and cannot make glucose.
- (O) I found that glucose travels through the veins to various parts of the plant.

(10) What is the process that involves the movement of materials through cell membranes?
- (K) Diffusion is the process by which things move through cell membranes.
- (J) The process that involves the movement of materials passing through cell membranes is called diffusion.
- (O) The process that allows the movement of material through the membrane is diffusion.

ARFVEDSON GRADE 7

INVESTIGATION 2

Legend: (K) = Karl's response
(J) = Jacob's response
(O) = Olaf's response
N.R. = no response

Pre-Laboratory Teacher Demonstration (student recorded observations)

Substance	Presence of Starch (K)	(J)	(O)
crackers	yes	N.R.	starch present
corn syrup	no		no starch
vegetable oil	no		no starch
laundry starch	yes		starch present
corn starch	yes		starch present
flour	yes		no starch
sucrose	no		no starch

Background Information Given In Class

The starch test
When brown (light brown) iodine is placed on starch the two react and turn black.

The use of food in plants
Food made by green plants is used for:
(1) energy
(2) growth
(3) tissue repair
Rapid growth of the cells at tips of stems and roots demands large amounts of energy. Roots are necessary to supply water and nutrients for leaf development and plant growth. Food stored in the form of starch supplies the energy to plants.

Investigation 2 - Laboratory Report Responses

Problem: When do plant leaves contain starch?
Purpose: To determine the effect of light on the presence of starch in leaves.

Observations:

Location of plant	Color change	Contains starch
leaf kept in the light for 24 hours	(K) green to dark black (J) N.R. (O) N.R.	(K) yes (J) N.R. (O) N.R.

ARFVEDSON GRADE 7, INVESTIGATION 2 (Cont'd)

leaf kept in the dark for 24 hours	(K) light green to light brown	(K) no
	(J) N.R.	(J) N.R.
	(O) N.R.	(O) N.R.

Questions

(1) What color is found with a positive test for starch?
- (K) Black
- (J) The color is black or purplish-grey.
- (O) N.R.

(2) Do these other materials give a positive test for starch? (sugar, alcohol, water, and vegetable oil)
- (K) No
- (J) Some do and some do not
- (O) N.R.

(3) In your notebook, draw the leaf and shade in the areas that are the golden color of the iodine solution. (For purposes of this study the diagrams are not replicated.)

(4) Is any color other than that of the iodine present?
- (K) Yes, black
- (J) No other color is present
- (O) N.R.

(5) What is this color, if any?
- (K) Black
- (J) The color is black
- (O) N.R.

(6) The starch molecule is formed when hundreds of smaller molecules of a certain substance are linked together, what substance produced by photosynthesis might have been changed to starch in the leaf?
- (K) Starch is made when lots of tiny glucose molecules link together.
- (J) Sugar might have been changed to starch.
- (O) N.R.

(7) Recalling the experiment you did in problem 13-2 with starch and sugar in the cellophane tubing, why do you think the starch particle is unable to move out of the cells?
- (K) From problem 13-2 I think the starch particle is too large to move out of the cells.
- (J) I think that the starch has big molecules.
- (O) N.R.

ARFVEDSON GRADE 7, INVESTIGATION 2 (Cont'd)

(8) In your notebook, draw the leaf and color the areas that are either yellow-brown or blue-black.
(For purposes of this study the diagrams are not replicated).

(9) Does the absence of light seem to change the amount of starch in a leaf?
- (K) When light is not present in a leaf, starch is not present in a leaf.
- (J) Yes, it does.
- (O) N.R.

(10) If starch is unable to get out of living cells, in what way might this be useful to the plant?
- (K) The plant can hold lots of energy without it diffusing.
- (J) The plant has more food to store and eat later.
- (O) N.R.

(11) What smaller molecules used to make the giant starch molecule can be used for food by the plant grown in the dark?
- (K) The plant in the dark could use glucose for food.
- (J) Sugar could be used.
- (O) N.R.

(12) Because plants grown in the dark lack glucose, the starch was broken down and used to produce energy. What factor tested in this experiment must be present in order for a green plant to carry out food-making activity?
- (K) A plant must have light in order to produce food.
- (J) It must have sunlight.
- (O) N.R.

EDITED LABORATORY REPORTS OF THREE SELECTED STUDENTS

CHADWICK GRADE 8

INVESTIGATION 1 (Relative Density)

Legend: (A) = Alfred
(M) = Marie
(I) = Irene
N.R.= No Response

Laboratory Report Responses

Problem
(A) What effect do the different mineral samples have on the relative density?
(M) What effect does the changing of a mineral have on relative density?
(I) What effect does relative density have on identifying minerals?

Hypothesis
(A) The water will raise and therefore we can find the relative density of the mineral.
(M) Relative density is probably one of the most reliable ways for identifying minerals. Some minerals which are unknown could possibly be identified by their relative density. I think relative density is very reliable for identification.
(I) I believe that relative density is reliable in identifying minerals because many minerals may not have the same relative density as one another.

Variable Identification
Manipulated variable:
(A) The weight of the mineral
(M) The different mineral samples
(I) The minerals

Responding variable:
(A) The amount the water raises
(M) Relative density
(I) Relative density

Controlled variables:
(A) The size of the mineral, the amount of water added, and type of mineral.
(M) Amount of water, size of beaker, same type of balance, same length of string, and same retort stand.
(I) Use the same beaker, use the same retort stand, and use the same triple beam balance.

CHADWICK GRADE 8, INVESTIGATION 1 (Cont'd)

Materials Required
As per handout.

Method
As per handout.

Precautions
(A) Watch that the beaker doesn't tip over and shatter.
(M) Do not let the sample touch the bottom of the beaker. Do not pick triple beam balance up by the beams. When using the string be careful that the balance doesn't fall off the table.
(I) One precaution is to make sure that the pointer is pointing to zero, otherwise the weight would not be accurate. Another precaution could be to make sure that you are using the proper mineral.

Data and Observations

mineral number	trial	mass loss in water (g)			relative density		
		(A)	(M)	(I)	(A)	(M)	(I)
	1	10.9	4.0	4.0	6.1	12.0	12.0
26	2	0.5	5.6	5.6	1.2	4.6	4.6
	3	9.1	8.5	8.5	1.8	7.6	7.6
	1	6.1	6.1	6.1	2.3	2.3	2.3
3	2	11.4	7.0	7.0	1.3	2.4	2.4
	3	8.2	5.9	5.9	1.9	2.7	2.7
25	1	34.0	34.0	34.0	3.6	3.6	3.6
	2	17.5	17.5	17.5	1.5	1.4	1.4
	3	1.4	1.4	1.4	2.7	2.7	2.7

Inferences
(A) What effect do the different mineral samples have on the relative density? Mineral samples have an effect on the mass loss in air and water. The gain would be the relative density.

(M) I feel that relative density may not be the most reliable way of identifying minerals because many unknown minerals are similar to each other and could even be similar in density also.
(I) I would say that relative density is not reliable in identifying, because each mineral sample differs even if it is the same kind of mineral.

CHADWICK GRADE 8, INVESTIGATION 1 (Cont'd)

Questions

(1) What is the meaning of relative density?
(A) A comparison of the weight of a substance to the weight of an equal volume of water.
(M) Relative density is the mass of an object when placed in water, the loss of weight from air to water will be density.
(I) Relative density is how dense a mineral is compared to water.

(2) A certain mineral has a relative density of 6.2. What would the relative density be if it were broken exactly in half?
(A) It would be exactly the same.
(M) When broken down, the relative density would still be 6.2.
(I) 6.2.

EDITED LABORATORY REPORTS OF THREE SELECTED STUDENTS

ASTON GRADE 9

INVESTIGATION #3 Student's Name Nicolas

Openended Investigation - Separation and Identification of Components in a Mixture

Problem Statement - To separate and identify as many components or substances as possible from the mixture.

This is What I Did
First the iron shavings are separated by a magnet, I got the bag of substance, I put it out on a piece of paper and then I got the magnet and took out every bit of iron shavings.

This is What I Saw
I saw the iron shavings when put close to the magnet they came over and attached themselves to the magnet.

This is What I Did
The second substance is sulfur separated by decantation. I put the substance in water, stirred it a bit and then put the sulfur that is at the top of the water in the bag, then poured the watery substance through a filter.

This is What I Saw
I saw the sulfur float to the top of the glass beaker, the sulfur was wet and lost its color.

This is What I Did
The third substance was the sugar, after I put the watery substance through the filter I took the clear water and put the water under a bunsen Burner in the evaporating dish, all that was left was a little sugar. I tasted it to make sure it was sugar.

This is What I Saw
I saw the watery substance go through the filter, I also saw the clear water evaporate into a sugar.

This is What I Did
The fourth substance is the beads after the wet substance dried I moved the rest of the mixture back and forth and separated the beads as a sample.

This is What I Saw
I saw the substance dry and I saw the substance being moved back and forth, I also saw the bead rolling down the inclined binder.

ASTON GRADE 9, INVESTIGATION 3 (Cont'd)

This is What I Did
The fifth substance was the sand I gathered it up and put it in a piece of saran wrap.

This is What I Saw
I saw the last substance being gathered up and put in saran wrap.

In Conclusion
I thought the experiment was a big success.

INVESTIGATION #3

Student's Name Rachel

Openended Investigation - Separation and identification of Components in a Mixture.

1. Problem Statement

To separate and identify as many substances as possible from the mixture.

2. Background Information

Decantation - pouring off.
Sublimation - changing from solid to gas or gas to solid without going through a liquid stage.

3. Hypothesis

The substances can be separated by their properties because some will be magnetic, some will dissolve, some will float on water and some will run down a tilted hard surface.

4. Design

Materials - mixture of unknown substances (iron filings, sugar, sulfur, beads and sand) water, magnet, hard substance (surface tilted) beakers, bunsen burner and filters.

1. Put magnet to mixture and get all of the iron filings.
2. Put mixture on a hard tilted surface (binder) and tap it lightly with your pen or finger and beads will go down to bottom first.
3. Put mixture in beaker with water and sulfur will float to the top.
4. Take mixture (that was in the water) and filter it, the sugar will dissolve and go through the filter paper and all that will be left is the sand.

ASTON GRADE 9, INVESTIGATION 3 (Cont'd)

5. Observations

The magnets attracted to the iron filings fast. The iron filings stuck to the magnet on both north and south ends of the magnet. The beads on the binder ran down right away. Some sand went down with it and some beads stayed with the mixture but, most went down.
When putting mixture with water the sulfur stayed on top while everything else sank to the bottom.
After stirring the mixture in, we filtered it. The sand stayed on the filter paper and the sugar particles went through.

	Magnet	Dissolve	Filter	Float	Rolled Easily
Sand	no	no	no	no	no
Iron Filings	yes	no	no	no	no
Sulfur	no	no	no	yes	no
Beads	no	no	no	no	yes
Sugar	no	yes	yes	no	no

Accept Hypothesis

The hypothesis that I had made before is accurate because you can see by the chart that each one had one thing that it did. For instance each either was magnetic, or dissolved, floats on water or ran down a tilted hard surface.

INVESTIGATION #3

Student's Name Elaine

Openended Investigation - Separation and Identification of Components in a Mixture.

Problem Statement

To separate as many different substances as possible from the mixture.

Hypothesis

You can separate the different substances in a mixture by many different methods.

Design

In order to separate the different substances in a mixture there are many different methods such as: filtering, decantation, dissolving and distillation.

ASTON GRADE 9, INVESTIGATION 3 (Cont'd)

Organization of Data

Substance Found	Method Used in Order to Find it
Sulfur	Pour a small amount of the mixture into a test tube and heat over a bunsen burner.
Beads	Pour the mixture on to a slope and lightly tap it (the slope).
Iron filings	Move a magnet over the mixture.
Sugar and Sand	Dissolving, filtering and distillation are the three things used to separate them.

Conclusion In conclusion I feel that using different methods you can separate the different materials in a mixture.

APPENDIX K

ANALYSIS OF OPINIONNAIRE DATA

TABLE 27

ANALYLSIS OF LIKERT ITEMS IN OPINNIONAIRE FOR GRADE SEVEN CLASS (N=20)

Statements	Percentage of Students Indicating Responses						
	S A	A	U	D	S D	Mean	S
1. Reading science is difficult	0	45	25	20	10	3.0	1.0
2. Spend too much time doing experiments	0	0	10	60	30	4.2	0.6
3. Leaning a lot in science	30	40	25	0	5	3.9	1.0
4. Do in class what real scientists do	0	45	35	20	0	3.3	0.8
5. Study to-day's problems in class	0	15	50	30	5	2.8	0.8
6. I dislike coming to science	5	10	30	35	20	3.6	1.1
7. Read more science now then in sixth grade	15	60	5	15	5	3.7	1.1
8. Enjoy doing science experiments	25	55	20	0	0	4.1	0.7
9. I can solve problems better than before	25	30	35	10	0	3.7	1.0
10. My friends enjoy science experiments	25	30	35	10	0	3.7	1.0
11. What I learn in science will be useful outside school	25	25	30	10	10	3.5	1.2
12. Think about what is learned in science when not in school	10	35	30	15	10	3.2	1.1
13. Do not want to take more science than I have to take	5	40	25	25	5	2.9	1.0
14. Reading science is more fun that it used to be	20	30	35	10	5	3.5	1.1
15. Experiments are hard to understand	5	40	10	25	20	3.2	1.3
16. Science is dull for most people	20	35	25	15	5	2.5	1.1
17. The things we do in class are useless	0	0	25	35	40	4.2	0.8
18. The kinds of experiments I do are important	25	25	50	0	0	3.8	0.8

TABLE 27 (Cont'd)

Statements	Percentage of Students Indicating Responses S A	A	U	D	S D	Mean	S
19. I learn a lot from doing experiments	25	60	5	10	0	4.0	0.8
20. Most people like science classes	5	10	50	35	0	2.9	0.8
21. I get actively involved in performing experiments	15	25	25	30	5	3.2	1.2
22. Most students discuss their findings within their lab groups	15	40	30	15	0	3.6	0.9
23. Member within my lab group do labs without getting into arguments	0	35	25	30	10	2.9	1.0
24. I enjoy working with my lab partners	35	50	5	10	0	4.1	0.9
25. Working with lab partners helps to to understand the experiments better	35	35	15	10	5	3.9	1.2
26. Pre-laboratory discussions are helpful	30	35	15	0	0	4.2	0.7
27. Laboratory experiments should not have so many instructions	5	25	25	35	10	2.8	1.1
28. Without post-laboratory discussions experiments would be a waste of time	20	30	35	15	0	3.6	1.0
29. Teachers give students too much help during laboratory activities	0	15	25	55	5	2.5	0.8

Note: Means and Standard Deviations (S) calculated on the basis of answer choices being weighted 5, 4, 3, 2, and 1. With 5 assigned to the choice and most favorable to science program. (See Appendix C)

TABLE 28

ANALYSIS OF ITEMS FOR THE GRADE EIGHT CLASS (N=25)

Statements	Percentage of Students Indicating Responses						
	S A	A	U	D	S D	Mean	S
1. Reading science is difficult	0	28	24	36	12	3.3	1.0
2. Spend too much time doing experiments	0	4	12	44	40	4.2	0.8
3. Learning a lot in science	12	76	12	0	0	4.0	0.5
4. Do in class what real scientists do	0	24	24	36	16	2.6	1.0
5. Study to-day's problems in class	0	36	36	20	8	3.0	1.0
6. I dislike coming to science	4	12	20	48	16	3.6	1.0
7. Read more science now than in sixth grade	44	40	8	8	0	4.2	0.9
8. Enjoy doing science experiments	48	36	8	8	0	4.2	0.9
9. I can solve problems better than before	0	68	28	4	0	3.6	0.6
10. My friends enjoy science experiments	12	44	32	8	4	3.5	1.0
11. What I learn in science will be useful outside school	12	36	40	12	0	3.5	0.9
12. Think about what is learned in science when not in school	4	12	24	40	20	2.4	1.1
13. Do not want to take more science than I have to take	8	28	40	20	4	2.8	1.0
14. Reading science is more fun than it used to be	4	12	20	36	28	2.3	1.1
15. Experiments are hard to understand	0	0	20	60	20	4.0	0.6
16. Science is dull for most people	4	24	40	28	4	3.0	0.9
17. The things we do in class are useless	0	4	16	72	8	3.8	0.6
18. The kinds of experiments I do are important	4	60	20	12	4	3.5	0.9

TABLE 28 (Cont'd)

Statements	Percentage of Students Indicating Responses						
	S A	A	U	D	U D	Mean	S
19. I learn a lot from doing experiments	16	48	24	12	0	3.7	0.9
20. Most people like science classes	4	28	40	20	8	3.0	1.0
21. I get actively involved in performing experiments	12	60	12	16	0	3.7	0.9
22. Most students discuss their findings within their lab groups	24	44	8	16	8	3.6	1.3
23. Members within my lab group do labs without getting into arguments	20	48	8	8	16	3.5	1.4
24. I enjoy working with my lab partners	20	36	12	20	12	3.3	1.3
25. Working with lab partners helps me to understand the experiments better	20	52	12	8	8	3.7	1.1
26. Pre-laboratory discussions are helpful	32	52	8	8	0	4.1	0.9
27. Laboratory experiments should not have so many instructions	4	16	36	24	20	2.6	1.1
28. Without post-laboratory discussions experiments would be a waste of time	28	44	16	12	0	3.9	1.0
29. Teachers give students too much help during laboratory activities	4	0	20	52	24	2.1	0.9

Note: Means and Standard Deviations (S) calculated on the basis of answer choices being weighted 5, 4, 3, 2, and 1. With 5 assigned to the choice most favorable to science program. (See Appendix C)

TABLE 29

ANALYSIS OF LIKERT ITEMS FOR GRADE NINE CLASS (N=22)

Statements	Percentage of Students Indicating Responses S A	A	U	D	S D	Mean	S
1. Reading science is difficult	0	18	14	64	4	3.5	0.9
2. Spend too much time doing experiments	0	0	4	73	23	4.2	0.5
3. Learning a lot in science	9	68	9	14	0	3.7	0.8
4. Do in class what real scientists do	0	28	27	45	0	2.8	0.9
5. Study to-day's problems in class	0	32	41	27	0	3.0	0.8
6. I dislike coming to science	0	9	18	41	32	4.0	1.0
7. Read more science now than in sixth grade	45	50	0	5	0	4.4	0.7
8. Enjoy doing science experiments	36	59	5	0	0	4.3	0.6
9. I can solve problems better than before	14	68	9	9	0	3.9	0.8
10. My friends enjoy science experiments	0	32	54	14	0	3.2	0.7
11. What I learn in science will be useful outside school	18	50	18	9	5	3.7	1.0
12. Think about what is learned in science when not in school	4	50	23	23	0	3.4	0.9
13. Do not want to take more science than I have to take	4	14	27	41	14	3.5	1.1
14. Reading science is more fun than it used to be	5	45	27	23	0	3.3	0.9
15. Experiments are hard to understand	0	4	32	59	5	3.6	0.7
16. Science is dull for most people	0	32	50	18	0	2.9	0.7
17. The things we do in class are useless	0	0	9	68	23	4.1	0.6
18. The kinds of experiments I do are important	9	59	32	0	0	3.8	0.6

TABLE 29 (Cont'd)

Statements	Percentage of Students Indicating Responses						
	S A	A	U	D	S D	Mean	S
19. I learn a lot from doing experiments	9	77	5	9	0	3.9	0.7
20. Most people like science classes	0	18	50	32	0	2.9	0.7
21. I get actively involved in performing experiments	9	64	14	13	0	3.7	0.8
22. Most students discuss their findings within their lab groups	9	64	27	0	0	3.8	0.6
23. Members within my lab group do labs without getting into arguments	4	59	23	14	0	3.5	0.8
24. I enjoy working with my lab partners	14	77	9	0	0	4.0	0.5
25. Working with lab partners helps me to understand the experiments better	36	50	9	5	0	4.2	0.8
26. Pre-laboratory discussions are helpful	32	68	0	0	0	4.3	0.5
27. Laboratory experiments should not have so many instructions	0	14	27	55	4	2.5	0.8
28. Without post-laboratory discussions experiments would be a waste of time	23	50	4	23	0	3.7	1.1
29. Teachers give students too much help during laboratory activities	0	0	23	73	4	2.2	0.5

Note: Means and Standard Deviations (S) calculated on the basis of answer choices being weighted 5, 4, 3, 2, and 1. With 5 assigned to the choice most favorable to science program. (See Appendix C)

TABLE 30

SUMMARY OF EDITED RESPONSES TO QUESTION 30

FOR GRADE 7

Student Number	Written Response
1.	I think science laboratory work is good but sometimes it's really hard.
2.	I think science laboratory work is sort of fun sometimes but it can also be fairly boring. I don't really see what we get out of science though.
3.	I think science laboratory work is sort of boring. Some of the experiments can be fun but not many.
4.	I think science laboratory work is very helpful for you in coming years to assist you for your job etc. It is also very fun but lets you learn things you didn't know before.
5.	I think science laboratory work is fun, and you can learn something new with every lab experiment.
6.	I think science laboratory work is very useful to you now and will be in the future. I learned more about science.
7.	I think science laboratory work is very important. It teaches you to think out problems and to use your head. It is very fun and exciting because you learn and see things you have never heard of.
8. (Jacob)	I think science laboratory work is helpful sometimes. But I still like science it helps me a lot and I love doing science experiments.
9. (Olaf)	I think science laboratory work is dangerous.

TABLE 30 (Cont'd)

10.	I think science laboratory work is okay. It helps you and some of the experiments are fun. But I like to work by myself because partners are a nuisance. Science laboratory work helps you learn more and you can use it out in the world.
11.	I think science laboratory work is okay but sometimes I find science boring and sometimes I don't.
12.	I think science laboratory work is good sometimes and bad sometimes.
13.	I think science laboratory work is to help me to understand and to answer questions that I do not know.
14.	I think science laboratory work is good because we do the experiments and see what is happening, for example, looking at quard cells under the microscope.
15.	I think science laboratory work is really boring sometimes because we have to do notes.
16. (Karl)	I think science laboratory work is the best possible way to learn. People tend to remember things more from first hand experience than from reading. Conducting an experiment also allows you to ask others to help you understand or vice versa.
17.	I think science laboratory work is fun and easy. It can also be useful in the future. Some of the experiments are hard but they are fun to do.
18.	I think science laboratory work is fun and interesting, may be useful in the future.
19.	I think science laboratory work is more involving of the kids, but sometimes the experiments are so boring, like watching water rise in a tube.
20.	I think science laboratory work is interesting, a good job and you become smarter.

TABLE 31

SUMMARY OF EDITED RESPONSES TO QUESTION 30 FOR THE GRADE 8 CLASS

Student Number	Written Response
1.	I think science laboratory work is a learning experience which may be helpful one day. It is sometimes a waste of time and very useless but can be interesting and educational. I think that it is a good experience in both science and everyday.
2.	I think science laboratory work is fun and interesting.
3.	I think science laboratory work is useful to us because it's easier to understand what the teacher is talking about if you can actually see it happen. Saying something is the way it is and see what it is; are two different things.
4.	I think science laboratory work is quite interesting because I learn from experiments and discussions. It is very fun to experiment with certain things.
5.	I think science laboratory work is quite boring. We do too much reading and summarizing and not enough real experiments.
6.	I think science laboratory work is very interesting in many ways but it upsets me by the fact that I can't use this knowledge in my future. I think that some changes should be brought up in the laboratory and that we do some things that will help the students and myself in our futures. What I mean by that is not all of us are going to be scientists.
7.	I think science laboratory work is doing different experiments, learning how and why it did that (cause). Learning different kinds of things; like rocks, liquids etc., the purpose of things on the earth's surface.

TABLE 31 (Cont'd)

8. I think science laboratory work is the most enjoyable part of science, but the summarizing and other stuff is a pain.

9. I think science laboratory work is helpful to me and I hope we get more chances to learn about today's scientific methods and procedures.

10. I think science laboratory work is helpful in allowing me to fully understand what we are talking about in class. It also allows me to compare how I am doing in the subject of science compared to my friends.

11. I think science laboratory work is really fun. I personally learn more when we do lab work because it's more interesting working with other people. So, if you are having trouble understanding something they can explain it to you in a way you understand. Textbooks are a little hard to understand so, if you see something done (an experiment) you will probably get exactly what they are talking about.

12. (Alfred) I think science laboratory work is a great way to help understand and solve a particular problem and eliminate any misunderstanding.

13. I think science laboratory work is interesting and you learn a lot from it. I think that experiments help you understand better what you are studying.

14. I think science laboratory work is very interesting. I especially like labs in which we use microscopes. Laboratory work is fun and you learn a lot.

15. (Irene) I think science laboratory work is boring at times, yet interesting at other times. We study boring useless stuff, I mean who really cares how crystals form? A large percentage of the information I learn will never help me in the future at all, not one bit.

16. I think science laboratory work is helpful because we can see what happens so we can understand the problem and why and how it happens, it helps to identify the terms and concepts better

TABLE 31 (Cont'd)

17. I think science laboratory work is interesting and fun, but sometimes it can be boring.

18. (Marie) I think science laboratory work is fascinating and intriguing. You discover and learn so much about the world, universe and things that you've never thought of before. Lab work lets you experience things that scientists study and it helps you to have a better understanding of what is happening around you today (hope that in the future, things I have learned will come in handy).

19. I think science laboratory work is fun and exciting but we should be able to choose what things we want to learn. As this would help us in understanding the careers we have chosen to do when we grow up. This will also help us to know what we are interested in and what will be useful to us in the future.

20. I think science laboratory work is o.k. for some people, good for some people and bad for some people, but personally the laboratory work is fun way of doing science with a group of friends you enjoy doing science with.

21. I think science laboratory work is in some ways fun and interesting, in others it really is not fun. It's equal really.

22. I think science laboratory work is fun and exciting but it could be better. (Don't think we work in lab enough and we work on reading and answering questions too much.)

23. I think science laboratory work is something you should learn but most of the time it is not enjoyable.

24. I think science laboratory work is fun and helpful in understanding ways in which to do some things.

25. I think science laboratory work is good and not good. I think that some experiments are pretty dumb, like the streak and luster test of the minerals.

TABLE 32

SUMMARY OF EDITED RESPONSES TO QUESTION 30

FOR GRADE 9

Student Number	Written Responses
1.	I think science laboratory work is helpful in a sense that it helps you get a better understanding of what you are doing in each particular unit. Its better to do them than to read about them. Its good to be able to do something more active once in a while than writing until your hand falls off.
2.	I think science laboratory work is a lot of fun, very educational and gets you thinking and wanting to do more.
3.	I think science laboratory work is fun and also educational.
4.	I think science laboratory work is fun in some ways and yet frustrating in others. I like to do some of the experiments because I find them useful, and some are just useless. I think there are a lot of fun things to do in science that will help us when we get out of school.
5.	I think science laboratory work is enjoyable when we do lab experiments but boring when we do straight work.
6.	I think science laboratory work is interesting and fun finding out new things, and is a good source of information for things happening within our universe in the future.
7.	I think science laboratory work is interesting because I know I understand it a lot better and it seems the experiments are getting easier but I guess it's because I understand them better.

TABLE 32 (Cont'd)

8.	I think science laboratory work is more interesting and keeps me awake rather than listening to boring discussions and readings all the time. When you actually perform an experiment you get more out of it than just listening to someone talk about it. It is easier to remember things about it when you actually do it.
9. (Rachel)	I think science laboratory work is helping me learn more and understand how things work, like atoms etc. The thing that I like to do most is experiments, but we don't do them often enough.
10.	I think science laboratory work is interesting and hopefully useful in my later years.
11.	I think science laboratory work is fairly interesting, and helps students understand the way things work, and what causes certain reactions (chemical or others) to take place. It helps students understand materials more, and it makes the class a little more interesting.
12.	I think science laboratory work is usually a lot of fun. I also think it is important in education.
13.	I think science laboratory work is (no comment made).
14. (Elaine)	I think science laboratory work is okay sometimes, depends what it is that we are doing. Some experiments I like and others I dislike.
15.	I think science laboratory work is fun and useful. It helps people to understand more, because they are actually seeing what is happening. It also gives an explanation to what ever the question was.
16.	I think science laboratory work is exciting most of the time when we are doing experiments but boring when we have to read from a text book or do written work.

TABLE 32 (Cont'd)

17. (Nicolas) I think science laboratory work is helpful to show you or make you understand more about what the experiment does, and what the experiment does to help you in everyday life.

18. I think science laboratory work is experiments that have to do with things all around us that will help.

19. I think science laboratory work is a way to learn easier than just reading it in a book and being able to know what really happens.

20. I think science laboratory work is helpful, educational, and fun, only if you know what you are doing.

21. I think science laboratory work is very interesting and educational. It helps me get a much better perspective on what I want to do in life, seeing as I want to become a doctor.

22. I think science laboratory work is fun, helpful and informative because its neat to watch the results and it is helpful because you know how to solve problems better.

APPENDIX L

INTERVIEW QUESTIONS

STUDENT INTERVIEW QUESTIONS INTERVIEW (1)

(1) What comes to your mind when you hear someone say school science laboratory work. How do you feel about that?

The next 11 questions relate to the answers you gave to some questions on the science opinionnaire.

(2) In question #4 what were your reasons for giving this answer?

(3) In question #5 why do you agree, disagree or were undecided with this statement?

(4) In question #10 why did you give this answer?

(5) For question #12 could you tell me more about this?

(6) For question #13 what are your reasons for saying this?

(7) For question #14 why did you choose this answer?

(8) In question #16 could you give me your thinking behind this answer?

(9) For question #23 could you tell me more about this?

(10) In question #27 why did you give this answer?

(11) For question #28 why did you choose agree (disagree, undecided)?

(12) In question #29 why did you choose this answer?

The next four questions pertain to the experiment you performed last day.

(13) Considering last day's experiment, what part of the investigation did you find most enjoyable?

(14) Which part of the investigation did you find most difficult?

(15) Did you require help from the teacher while performing the experiment? Did the teacher come around to your lab table? Do you like the teacher to visit your lab table? Why?

(16) Did you know the results of this experiment before you performed it? Did it encourage you to think or want [illegible] answer to the problem? How?

STUDENT INTERVIEW QUESTIONS (INTERVIEW 2)

(1) Could you learn about the scientific concepts as well without doing any lab work? Why?

(2) Do you find lab reports to be helpful? Why or why not? How often were you required to prepare lab reports this year?
Do you like preparing lab reports? Why or why not?

(3) Would you like to do laboratory work by yourself, without a partner? Why?
Would you tend to learn more if you had to do all the work?
Would you like to be in a lab group where you were the only girl (boy)?

(4) How much time, percentage wise, have you spent in doing lab work in grade 7, grade 8, or in grade 9 this year?

(5) Do most of your laboratory experiments indicate or teach you something new, or do you know the answers most of the time before you perform the experiments? Could you explain this more to me?

(6) Do you like doing the series of questions provided in some investigations, i.e. inference questions, application questions, etc. better than doing lab reports? Why?

(7) Do you read through your lab investigations before coming to class? Why or why not?

(8) Do most laboratory experiments tend to improve your skills in manipulating equipment? Why do you feel that way? Does doing lab work also improve your observational skills? How do you know?

At Aston school the interviewed students were also asked about the open-ended investigation they had performed.

The next few questions relate to the investigation you did on Separation and Identification of Components of a Mixture:

(9) Do you like doing that kind of experiment? Why?

(10) Did you require the teacher's help more in this experiment than you do in the regular type of experiment? Why? Did you require greater assistance from your lab partners? How?

(11) Do you feel confident that you understand the purpose for doing this experiment? Why do you feel that way?

(12) Did this investigation challenge you more than the regular type of investigations? In what way?

STUDENT INTERVIEW QUESTIONS (INTERVIEW 3)

(1) Would you like to, or prefer, to work on experiments that you devised or invented yourself instead of the ones you have been working on so far this year? What would you be choosing as areas to work on? What would your response be if you were told you still had to work on chemistry, biology, or physics topics?

(2) Do you prefer to handle the lab equipment yourself in doing experimental work, or would you rather watch someone else do the experiment? Why?

(3) How much time do you spend in doing science homework compared to other subjects? How much time would this be within a normal week? How much of this homework is related to laboratory work?

(4) Would you like to construct, in the laboratory, some of the simple machines and apparatus that you use to carry out experiments? How would this be of assistance to you?

(5) After performing an experiment can you usually notice things outside of school where you could apply what you learned in the experiment? Could you explain this further?

(6) When you go to the laboratory to perform experiments how do you usually feel about knowing what you are suppose to do?

(7) What is your response to a statement like this; the laboratory period is a play period?

(8) When you perform an experiment can you usually see why it is important for you to be doing that particular experiment? Why do you feel this way?

(9) Could the lab partners in your group usually use their time more effectively during lab work than they do? How?

(10) In your lab group there are 3 or 4 members. Does everyone in your group have a chance to become involved, or are some left out? Explain.

(11) After having gone through a class discussion before a lab, performed the lab, and then had a class discussion after the lab, do you usually feel satisfied, frustrated, dissatisfied or what? Why?

(12) Which type of experiment do you like better; the ones

where you get some numerical readings - numbers from instruments or the ones where you obtain information through your five senses - smell, sight, hearing, feel, and taste? Why?

(13) If you had your way what changes, if any, would you like to make in how class discussions before and after laboratory work are organized? Why?

(14) What things do you dislike most about science classes? Explain?

(15) Would you like to have all lab partners who are weak students? Why? Why not?
What about having lab partners who are all very smart, honor students?

(16) How do you feel when confronted with unfamiliar equipment?

TEACHER INTERVIEW QUESTIONS (INTERVIEW 1)

(1) Why do you like to have your students involved in laboratory work?

(2) What, in your opinion, does laboratory work do for your students that cannot be, or at least cannot be accomplished as well, through other instructional methods?

(3) What other instructional methods do you use besides laboratory work? Why?

(4) How much laboratory work do your classes do at each of the grade levels, 7, 8, and 9?

(5) What types of teaching objectives or goals are most effectively fulfilled by doing lab work?

(6) Do you feel that the scientific processes are useful in teaching of science, particularly for doing lab work? Why?

(7) Do you follow the structure of pre-lab, lab experiment and post-lab discussion in all your lab work, or do you use other structures?

(8) At the junior high school level how do pre-lab and post-lab discussions assist students?

(9) How do you usually group students for laboratory work?

(10) Do you find that sometimes lab partners don't work well together? How do you attempt to resolve such situations, if they arise?

(11) Do you use the teacher demonstration method? If so when do you use it, and how effective do you find it to be?

(12) Do you feel that completely open-ended scientific inquiry, in other words, unstructured laboratory instruction would work at the junior high school level on a regular basis? Why or why not?

(13) Do you use laboratory exams (non-paper and pencil tests)? Why or why not?

(14) Who gathers the lab equipment for your classes' involvement in lab activities? (puts away equipment, washes-up lab equipment?)

(15) Do you feel that lab work involves the teacher in having to put forth more effort than may be required in other instructional methods? Why or why not?

(16) Does lab work involve students in having to do homework? Why or why not?

(17) How do students prepare for doing laboratory work? Do they read the experiment before coming to class, are they encouraged to read sections in a book, or what?

(18) Which techniques serve you well in organizing laboratory activities at the junior high school level?

(19) How active should teachers be in assisting students while they are performing their lab investigations? Why?

(20) Do most laboratory experiments teach students something new, or do they know the answers before they begin? Explain?

TEACHER INTERVIEW QUESTIONS (ASTON SCHOOL - INTERVIEW 2)

(Investigation 3) (Open-ended Investigation)

(1) How much previous experience have students had in using the methods for separation of a mixture?

(2) How familiar are students with writing of lab reports using scientific processes?

(3) Were all student mixture samples for this investigation the same?
How many different components do their sample mixtures contain?
What are the components?

(4) As you walked around the room assisting and talking to students, what in your opinion, were students having most difficulty with in this experiment? What did they seem to find easiest?

(5) How much teacher guidance did students require in performing this experiment in comparison to a regular laboratory investigation where they are provided with all the necessary instructions within their lab notes? What kind of questions were students asking you?

(6) In relation to an experiment which provides students with a list of materials, design, prepared charts for recording data, inference questions and so on; how does this experiment compare as a learning experience for students?

TEACHER INTERVIEW QUESTIONS (ARFVEDSON SCHOOL - INTERVIEW 2)

Problem 14-1: Food Produced by Green Plant (Investigation 1)

(1) Do you find the experiments as outlined in Life Science - A Problem Solving Approach to be adequate for your purposes, or do you frequently have to modify them?

(2) In the pre-lab discussion for problem 14-1 (the experiment performed last day) what kinds of things would you stress to students?

(3) What in your opinion did students appear to be having most difficulty with as they performed the experiment for problem 14-1?

(4) As you walked around the room watching and helping students, did you feel that students understood what they were doing in this experiment, or did they need more teacher assistance than usual?

(5) In you view did the experiment give all the groups what they were looking for? (i.e. was the experiment successful?)

(6) In your opinion do students like doing the questions associated with the experiments? Do they find the questions helpful? How?

TEACHER INTERVIEW QUESTIONS

(ARFVEDSON SCHOOL - INTERVIEW 3)

INTERNAL STRUCTURE OF A LEAF (INVESTIGATION 3)

(1) In the last investigation, Internal Structure of Leaves, students used the microscopes to observe slides of leaves. How well acquainted are students with using microscopes?

(2) In this investigation students were required to make a drawing of the cells found inside a leaf. In your experience, generally how well do students perform this kind of task? Do they usually remember to label their drawings or do they frequently have to be reminded?

(3) When students are required to prepare their own slides do they have a task which they can handle adequately? Do their slides usually provide them with observations they are expected to obtain? How often have students prepared their own slides in the past?

(4) In this investigation there was a diagram provided of a cross section of a leaf, are students able to see all of these parts when they are observing their slides with the microscope? Does the diagram provided in their notes make it too easy for them, why or why not? Wouldn't the description of leaf parts, as provided, be enough help for them?

(5) When looking at the cross section of a leaf there are a number of names of cells that students need to become acquainted with, how does the lab work assist them to do this?

(6) According to your experience do students generally enjoy working with microscopes and microscope slides? Why is this so?

APPENDIX M

SUMMARY OF TEACHER INTERVIEWS

TEACHER INTERVIEWS

Interviews with teachers are summarized under sub-headings which are applicable to all three teachers. Quotations are used to supplement the interpretations of the response statements made. All of the interviews conducted with a teacher are combined into one composite and then kept together when providing the interview summaries for that teacher under the sub-heading discussed. As the interview statements of one teacher are completed under the particular subheading the statements for another teacher are begun immediately without another subheading title.

Pre- Laboratory

(1) Laboratory safety is considered as an important aspect of pre-laboratory discussions. Students are often involved in laboratory activities where safety is of utmost importance.

> Scheele: Sometimes you have to forget about the content when you are doing labs, this is one thing that kind of bothers me, and you have to spend more time on safety rules, manipulation, and stuff like that.

(2) When teaching grade 7 students it is important to remember that most of the students have not been involved in laboratory activities previously, and therefore additional time is required in assisting them to adapt.

> Scheele: With grade seven you have to take it fairly slowly....what we take for granted they have never used before, and maybe never seen.

(3) The three phases of pre-laboratory, laboratory and

post-laboratory are used in all laboratory work.

> Scheele: It's a structure that we tend to use for much of the lab work. The pre-lab mainly for safety, to make sure kids understand directions and for introducing the concepts. Then the actual lab, and then talking about the results.

(4) Students are frequently grouped for laboratory work essentially as based on their seating location which they have selected within the room. Individual students are then removed from the group if they misbehave or don't function as expected.

> Scheele: Students are grouped by the way they have chosen to sit. If they don't behave where they are at they just sit down and don't take part in the lab. If he doesn't work with the kids he wants to work with, then he can sit down and find some other way to learn science. Give him a book or something.

(5) Without the assistance of a laboratory aide to prepare materials, set-up and take down laboratory equipment, it is more difficult to do laboratory work.

> Scheele: Our lab aide is a good typist, she looks after the books, the ordering and stuff like that. But we set up labs ourselves, I think that is one of the reasons some teachers aren't doing much lab work... The materials that we bring out for them are usually on a cart...Students are responsible for replacing these materials back on the cart when they have finished the experiment.

(6) Students have to be reminded of things like labelling diagrams and using of certain techniques, even after they have been used on previous occasions.

> Scheele: We are talking about junior high school kids and so the same rules apply. You remind and remind, and then you remind some more. That's standard so you know that it is going to happen.

(7) Pre-laboratory, laboratory and post-laboratory phases are important in all laboratory activities.

Dalton: I never do a lab without discussing it before and after, the after sometimes does not come until I have handed back their work, if I have taken it in, because it has more meaning, if they have it in front of them. I just feel it is useless otherwise.... I don't truly see how anyone can do lab work without them.

(8) A pre-laboratory discussion assists students by helping them to understand the experiment and relates the experiment to the concepts being learned.

Dalton: The pre-lab discussion clarifies instructions, clarifies the reason for doing the lab, some kids have a lot of trouble, they can do the labs and follow the directions, but don't have a clue of how it relates to what they are learning.

(9) Assigning students to laboratory groups prior to going to the laboratory helps in setting the tone for laboratory activities.

Dalton: I group them by assigning them to groups.....I have to have total control if I am running a lab. If I choose the groups then the kids know that I am going to run the classroom. It is a very subtle psychological tool but I think it is useful and it works.

(10) Any problems that arise within laboratory groups can usually be solved by moving students out of the group.

Dalton: I probably would move them and make new groups.

(11) Having a part time laboratory aide still leaves the teacher with much of the work.

Dalton: You might have a lab aide for part of the time, but you are still responsible for equipment, the shape the equipment is in, repair and inventory, you have an increased load in marking every week, especially if you have them do lab reports.

(12) Pre-laboratory discussion is used to emphasize safety and also for structuring of what students need to do.

Priestley: One of the very important aspects of pre-lab is emphasizing safety. I don't mind repeating myself every experiment to drum in the safety aspects because I think that is one of the important things when they go on on to chemistry 10, 20, and 30, or any of the science courses. In the pre-lab we do a lot of structuring, just nailing down exactly what it is they are going to do, and how this particular experiment relates to the concepts. Sometimes, they forget the major concept that we are investigating. For instance, they get stuck in on separating iron filings from the mixture and forget the concept we are focusing on. We try to put the tree into the forest sort of thing, so that they see the whole picture and that they are just working on little parts of it.

(13) Grouping of students is done from where students have chosen to sit, and therefore they are supposedly with people they want to work with.

Priestley: I usually do it by physical proximity and if there are difficulties that arise then I deal with those as they come up, but we don't seen to have very many problems with so and so won't work with somebody else. ...I don't have to deal with difficulties very often because where they are sitting in the class is of their own choosing. So they have picked people they would like to work with to sit beside. So when I group them they are almost in those groups already, with people they want to work with. But, if it is too much socializing then I will start to move them around.

Laboratory Work

(1) If students are not willing to work in a laboratory activity situation, then they should not be allowed to participate. Fooling around in a laboratory can be dangerous and a waste of time.

Scheele: If they are not going to work in a lab situation, you just shut them down for a while and get them taking notes....When giving privileges you have to be prepared to take them away, and lab work is a privilege.

(2) Engaging students in laboratory activities requires more effort of the teacher, not only in preparing for the lab, but also during the laboratory phase.

Scheele: I notice the difference when I am running almost all labs. .....yes it is a lot more stressful when you have labs, and people don't realize that.

(3) Using trays to set out and store materials and equipment makes it easier to keep track of it in the laboratory.

Dalton: I use the trays to set out and store materials and equipment, so they know where their equipment is and they can put it back. It also helps me to keep track if something is missing, if something is missing at the end of the period, I know exactly which group is responsible for it.

(4) During the laboratory phase the teacher should supervise and assist students.

Dalton: I think that teachers should be there and monitoring the situation. If they see an obvious problem, like a student not even carrying the method out properly then they should step in. .....Also students have questions and I think you shouldn't just walk away, you should stop to answer.

(5) Students given as few direct answers to their questions as possible while performing their experiments.

Priestley: If it is a situation where they have read the notes and they are still bogged down then I will try and give them some hints.

(6) Laboratory work is investigating rather than proving or disproving of previous learning.

Priestley: I kind of look at lab work as investigating not proving, and often I would not after posing a problem give a possible answer until the investigation is over and then what are your conclusions.

(7) In open-ended investigations where students are using techniques that they have learned previously, students should be able to perform the lab without teacher assistance.

Priestley: They often said how do we separate this, and I said just go back and look at the different techniques we have learned. I was really obstinate and miserable I didn't really give them any help. .....They really didn't need it, because between the members within each group they had sufficient expertise to come up with an answer.

(8) Student experiencing difficulty in their groups during laboratory activities are moved to another group.

Priestley: You are always going to get the difficult person, in that case, I look for a group that is more accepting of that particular person's, maybe defiant behavior, and that they will sort of keep it under control as best as possible.

(9) Laboratory work requires more effort of the teacher than needed for other instructional methods.

Priestley: It would be easier not to do laboratory work. It consumes energy and time just watching all the equipment and watching that they don't do any harm to themselves.

(10) As much of the assembling of equipment as possible is left to students as a learning experience.

Priestley: Some of the equipment I set up myself at the stations, but I rather put it out and let them construct it themselves. For example, in the distillation experiment which we did, I put out rubber stoppers, test tubes and a straight piece of glass on the tables and they would have to bend the glass into a right angle. So I leave as much of the manipulation and assembling of the equipment to them as possible. I also don't measure out the chemicals; if it calls for 25 grams of a chemical, I don't measure that out for them. I tell them they have to do it, and I leave the supplies either at the front, or on a trolley and they get it themselves. So I really tend to learn as much of the manipulation and building of equipment to them as possible.

Post-Laboratory

(1) Students are responsible for cleaning up their laboratory tables after completing a laboratory investigation.

Scheele: They will be asked to stand beside their lab stations so that we can check them to make sure they are cleaned up.

(2) A post-laboratory discussion makes the concepts studied more real for the students.

Dalton: In the post-lab discussion they get the concept along with the lab.

(3) Even in grade 7 students need to learn how to prepare laboratory reports.

Dalton: In grade 7 they should have to prepare their charts, graphs, and so on. They don't very often just fill in the blanks to questions that are asked.

(4) Post-lab discussions wraps up and shows how concepts studied tie in with the laboratory work, and it also provides for practical application to every day life.

> Priestley: The post-lab discussion is sort of where we wrap up and show how this fits in, and then we would look for practical applications in every day life of how this might be used.

(5) It is important for students to examine why an experiment didn't produce the results as predicted in a book.

> Priestley: Maybe it didn't come out the way the book predicted it would, but if it didn't there is a reason for that. And of course experiments don't always go the way the book said they would.

Scientific Processes

(1) Perhaps, not enough effort is being made in teaching applications of lab work and scientific processes to every day situations.

> Scheele: We don't make a great enough effort to try to apply things to say here is what is happening today, the old application thing again in science. I don't think we make enough of an effort to do this because that is a lot of work.

(2) Scientific processes are very useful in teaching of science.

> Dalton: The scientific processes put an order to things, it helps students to think logically.

(3) Laboratory reports assist students in developing their writing skills and in learning of the scientific process skills.

> Dalton: I think lab reports help them to organize them-

> selves. I know as a student myself when I learned to write a lab report I also learned a lot about essay writing for example. Stating your intentions and summing up things that happened, it really helps them that way. I think it helps with their writing skills if they have to provide written answers. It is always going to help them. .....It also helps in learning their process skills. If they have to identify the problem, if they nave to pick out variables then they are learning something about the scientific processes and why they are doing it. If they don't know why they are doing it then they are just putting in time.

(4) Scientific process skills can be used as a series of steps in organizing laboratory work. Students need to learn when to apply each of the processes.

Priestley: It is much easier when they are writing up the experiment just to have a series of steps to help you to organize, and I tend to put it that way to them, that they are not something unto themselves to be understood. .....Well, once they grasp the fact that they are just steps and you choose the steps that you need for a particular experiment, then they roll with the processes and they find them an assistance rather than a hindrance.

Level of Inquiry

(1) For investigations which have considerable structuring by the laboratory manual or teacher, the inference questions are provided to guide student interpretations of the observations made. Some students don't mind doing these kinds of questions and they help the students to feel confident that they have understood the investigation.

Scheele: I never found that the kids really didn't like doing those questions as long as they are fairly straight forward and you give the challenging questions at the end, so that the better students can do some thinking.

(2) Investigations where students have to write their own inferences, after making observations, are also useful and used occasionally.

Scheele: There is room for that too and it is something I do with all my classes, especially with my grade nines. Three times during the year they write out experiments.

(3) High level inquiry for junior high school students doesn't appear to work too well, except perhaps for the better students.

Scheele: I never found that open-ended stuff to work with these kids. For 5 to 10% of your kids it does. These are capable of handling that type of thing, but for the majority of junior high school kids its just a waste of time they just get lost, they have no reference point, you as a teacher are running around trying to answer all sorts of questions. .....I think there is a place for it, but you can't do it very often.

(4) Most of the laboratory activities tend to be of the verification type, low level of inquiry.

Scheele: It is unfortunate but in our schools we are trying to hit the mass majority. You can't go open-ended because you would lose 80% of the kids. You can't just give them notes, so you try to get these labs as verification, and you call them experiments even, but are they really experimenting, are they unsure of the results, probably not.

(5) Open-ended inquiry has to be kept simple and can be used only occasionally.

Dalton: Open-ended inquiry has to be kept very simple. I use it in the teaching of processes, as a culmination of the whole thing. ....I have them make up the lab, but they are told what they can use and I give them the problem.

> ....It's not an ongoing procedure, it's more of a teaching of the processes than anything.

(6) Open-ended investigations at the end of a unit of work indicate whether students have understood what they have taken.

Priestley: I think it is important because it tells me whether they really understood the work taken before, and if they can draw on these things to answer another question, it's really an application, synthesis and analysis.

(7) Students probably could not work on open-ended investigations on a daily basis.

Priestley: I think they need quite a bit of structure before they can work into that, they just don't have the prior knowledge, they don't have have the background they can draw on just to have sort of open-ended questions.

Impacts of Laboratory Activity

(1) Laboratory activities help students to be motivated and become involved in the learning process. They also allow for a feeling of independence and pride.

Scheele: I think if it wasn't for the motivational aspect, I don't know if I would do lab experiments or not, because they are a hassle. But it does motivate the kids. .....kids get kind of excited when they see something working out that they have actually done themselves.

(2) Besides laboratory work being a motivational device it also helps to fulfill objectives concerned with: teaching the scientific processes, manipulating and observational skills, cooperating with others, and interpretations.

Scheele: I don't think kids can understand the scientific method until they actually

> handle things and see that things can go wrong, understand that there are better ways of doing things, and understand controlled and other types of variables, that experiments need to have some variables controlled or they don't work out. School is also a socializing process, and if you are working in a group, which you have to do for lab work, then you have to assign tasks to group members, I'll do this, you do that and obviously that is also a problem, but it can be a benefit too.... the kid is in a better position to interpret something if he has actually done it..... scientific processes are not valuable as terms on a piece of paper, not at all. Kids have to actually do labs and then understand by doing the lab what those terms mean, like in grade seven I start them off with the terms, but I take them through a simple experiment like boiling water. They see that the equipment has to be set up, and they see where you have to put down directions. If you don't have good directions people can't do the lab. .....Without a lab I don't think you can understand why we need the scientific processes.

(3) Laboratory work provides an opportunity for teachers to socialize with students; however, teachers are often busy with so many other tasks that they are essentially unable to avail themselves of this opportunity.

> Scheele: That is another real advantage of lab work, you can go around and see the students individually, or groups of students. ..... Maybe we don't do that enough. We are too busy dealing with problem cases. ......I try to do that, I try to go around to every kid even if they are not having problems, just to see how it is going. There is again the old student teacher ratio showing up, and I don't know how I would solve that. Because during lab work you are going around and you are watching, commenting on things.

(4) Allowing students to see it for themselves during a laboratory investigation reinforces the concept being studied.

Scheele: If you hear about it, see it on a diagram, but then actually find it, see it for yourself, that really reinforces it. These aren't fictitious things any more. Here is a leaf and I can see these things. ...kids are still inquisitive at this age. They like to see things

(5) Even though laboratory activities take extra effort and are more stressful they are still worth doing.

Scheele: Lab work is good for the kids, its a motivational thing, and I can't see teaching science without it. It's part of the territory, you have to do it.

(6) Laboratory activities give variety to the teaching method and provide an additional learning style, particularly for those who learn by doing.

Dalton: It adds variety to the situation, because you have different kinds of learners and so you try to get something across to everyone. ..... because you have a variety of developmental levels there are lots of kids that need to see in order to understand, need to manipulate in order to understand, so it helps especially those children.

(7) Laboratory work helps to get concepts across, and teaches organizational and social skills.

Dalton: I think laboratory work helps to get concepts across, but I think it also teaches them organizational skills, it teaches even some social skills in terms of learning to work with others.

(8) Lab work is more stressful for the teacher than other teaching methods.

Dalton: If I run four or six classes of labs in a day, I am completely exhausted at the end of the day. ....It's really exhausting because you are on your feet, there is more stimulation in the class, there is more noise. It is not conscious but it wears on you.

(9) Ideally it would be nice if teachers could socialize more with students during laboratory activities.

Dalton: Well, I guess ideally that would be nice, but when you have thirty kids working in a lab its not always possible. Really you are to be twelve places at once. It comes down to bodies.

(10) Some students may find open-ended inquiry laboratory activities frustrating because they are so accustomed to doing low level inquiry investigations.

Priestley: Some probably find it very frustrating because they like to work strictly with instructions; a step by step process. Maybe that's our fault, we do this with so many experiments and then we cut it off and so they are not quite sure what to do.

(11) Laboratory work gives a longer lasting effect on retention rate, tends to motivate students, makes theoretical concepts more concrete, and makes students more scientifically literate.

Priestley: I firmly believe in the saying "I see and I remember little, but when I do I remember more" or something to that effect. I think for many of the kids this is very true that when they manipulate and actually do the experiment themselves it has a longer lasting effect, their retention is greater. Plus I think it is a great motivational factor. ...I think it brings the concept studied from the abstract to the concrete level. ...I kind of think of lab work as generating interest, and hopefully making them, lets say more scientifically literate. So that when they hear a report that a train accident resulted in a chemical spill they have some cognizance of what is involved in that. What is involved in clean-up or what happens when some of the chemical gets into the water system.

(12) Even with the extra effort required to do laboratory

work it is still worth doing.

Priestley: But I think the benefits out weigh the work required. So it is worth while doing.

(13) Socializing with students during laboratory work has merit, but finding the time to do this is difficult.

Priestley: You tend to leave the ones who are doing well on their own and help the ones who are bogging down.

Use of Other Instructional Methods

(1) A number of other instructional methods, besides laboratory work, are used in the science program provided to students. Use of various teaching methods allows for needed variety.

Scheele: Notes occasionally maybe 10% of the time, lab work 50% of the time, A.V. materials 10 to 15% of the time, discussions 10-15% of the time, independent projects, especially in grade 9, 10-15% of the time, and fairly major investigations occasionally . .....These other instructional methods are used for a variety of reasons, the more different ways you can teach something the better off you are. Lab work is a nice break, the kids are then ready to take notes occasionally, or willing to answer questions, or see a movie, it just breaks things up nicely, its a variety.

(2) Lab demonstrations are found to be effective and used for motivational purposes and covering optional materials.

Scheele: Any time I use demonstrations the motivation is there. We try to use them for little things we normally wouldn't cover.

(3) Other instructional methods also allow for different student developmental levels and learning styles.

Dalton: Audio-visuals, discussions, lectures, seat work, field trips, and things like that. These are used for variety to assist different students, in other words to give everybody an equal chance.

(4) Some of the grade eight units do not lend themselves well to doing a lot of laboratory activities.

Dalton: I find astronomy and meteorology to be two very difficult units to cover by doing a lot of laboratory work, there is some, and these are big units in the grade eight course.

(5) Silent teacher demonstrations provide an effective teaching technique when used occasionally.

Dalton: I find silent demonstrations to be very effective. Let the kids incorporate processes, like you hypothesize what is going to happen, I am not going to say anything, I want you to write down why, what, and how. They have to be involved in the demonstrations, although they are sitting, they are still involved.

(6) Use teacher demonstrations as a motivational device or when it is a more practical and safe way of doing the experiment.

Priestley: If it is an experiment that poses more of a hazard than normal then I will do it, or if it will produce, let's say a noxious gas, then I want to do it in the fume cabinets, or if it is practical to do it only once or twice then I will do a demonstration. .... I use them just as a motivational device, an excitement builder.

(7) A number of different instructional methods are used in teaching science classes.

Priestley: I do as little of the lecture as possible, just a time saver I prepare probably 60 to 70% of the students' notes so that we can read and discuss. I will do some demonstrations, or if I can find audio-visual materials that work then I use them. I get some people from industry, e.g. get people to come in and do demonstrations with

> low temperatures. For the grade eights a lot of field trips, I find that great for astronomy and especially for geology.

Lab Exams

(1) Laboratory exams are only used 3 times a year to assess students.

> Scheele: Twice during the year in grade nine and once in grade seven lab exams are used. But you talk about a hassle again. In grade 9 I give one when we finish the density - specific gravity - buoyancy section. It's one I have been using for the last 3 or 4 years. But even then it takes me 3 hours to set up.

(2) Laboratory exams are very difficult to administer.

> Dalton: I think lab exams are a great idea. I had a student teacher do it once, and it worked out fine because I was there to help out. If there hadn't been two of us, we couldn't have done it.

(3) Lab exams are used to evaluate students, but not to any great extent.

> Priestley: We don't do an awful lot of lab exams.... For density, they would be provided with four or five samples of which they could have to find the density.

Amount of Laboratory Work Done

(1) Laboratory work makes up a substantial part of the science courses offered.

> Scheele: I try to make it 50% all the way across. Grade nine might even be a bit more than that because they do a lot of lab work. Grade seven might be a little less than that.

(2) Laboratory work makes up half or more of the science course provided.

> Dalton: About 70% at grade 7 and 9 about 50% at grade 8.

(3) About half of the grade 9 science course offered consists of laboratory work.

Priestley: For grade nine I would think up to 40%.

EXAMPLE OF TEACHER INTERVIEW TRANSCRIPT

TEACHER INTERVIEW - ASTON JUNIOR HIGH SCHOOL

TEACHER'S NAME: PRIESTLEY (Interview #2)

1. Jeske: Why do you like to have your students involved in laboratory work?

2. Priestley: I firmly believe in the saying "I see and I remember little but when I do I remember more" or something to that effect. I think for many of the kids this is very true that when they manipulate and actually do the experiment themselves it has a longer lasting effect, their retention is greater. Plus I think it is a great motivational factor for many of the students to be able to do something rather than sit and listen or sit and watch. So a combination of these things.

3. Jeske: What key thing, in your opinion, does laboratory work do for your students that cannot be, or at least cannot be accomplished as well, through other instructional methods?

4. Priestley: I think it brings the concept studied from the abstract to the concrete level, that this is something they can manipulate. In the next experiment we are doing, we talk about chemical reactions. That can be rather airy fairy when written on paper but when they are actually pouring the two components, where they see a change taking place, now they feel they had something to do with this chemical reaction. So it brings down the abstract to the concrete. As you have observed some of the kids who are not very good at all with the written work really get stuck into doing the manipulative things.

5. Jeske: What other instructional methods do you use besides laboratory work?

6. Priestley: Well I do as little of the lecture as possible, just as a time saver. I prepare probably 60 to 70% of the students' notes so that we can read and discuss, or I will do some demonstrations, or if I can find an audio visual that works then I use that, I get some people from industry in occasionally to do demonstrations that are related, i.e. people to come in and do demonstrations with low temperatures. For the grade eight a lot of field trips, I find that great for astronomy and especially for geology. I use the river valley which is so close here, I use it extensively and this is a great occasion to see

different geological functions. Those are the ones that come to mind quite quickly.

7. Jeske: The field trips in a sense are an outdoor laboratory type of activity.

8. Priestley: Yeah it is, especially for the grade eights, its just an outdoor lab, and we do all of the pre and post-lab work for it.

9. Jeske: How much laboratory work do your classes do at each of the grade levels; 7, 8 and 9?

10. Priestley: I don't teach grade 7, but for grade 8 in the astronomy unit there is not very much manipulation of, we are building models of. In the geology section again it is mostly outdoor lab work, there is a lot of hands on; different rocks and minerals, specimens; that kind of thing. With the weather unit (meteorology) there are a number of experiments there we can do, say in relation to creating clouds, pressure, temperature and so on.

11. Jeske: In terms of percentage how much lab work?

12. Priestley: For grade eight I would think as low as 20%.

13. Jeske: What about grade nine?

14. Priestley: For the grade nine I would think up to 40%.

15. Jeske: So it is quite a bit more?

16. Priestley: Really not because of the kids but just because the curriculum lends itself better for labs.

17. Jeske: I think you would find that in most schools.

18. Priestley: I would think so, the astronomy unit doesn't lend itself to a lot of lab work, which is unfortunate, because if you could do some star gazing it could be a tremendous benefit.

19. Jeske: But that is at night?

20. Priestley: Yeah, you need a good machine (telescope) and you need to be outside the city.

21. Jeske: What type of teaching objectives or goals are most effectively fulfilled by doing lab work?

22. Priestley: I kind of think of lab work as generating interest in, and hopefully making them let's say more

scientifically literate. So that when they hear a report that a train accident resulted in a chemical spill, they have some cognizance of what is involved in that; what is involved in clean-up, or what happens when some of the chemical gets into the water system. They are always quoting tests, you know, on this soap powder is better than that soap powder. Why is it better? How can they prove it? Could the kids sit down and prove that? Just so that they are scientifically aware, or I think of everyday applications of science. Those are the general objectives that I have, and with the grade nine students you are looking at the preparation for the 10, 20, 30 series; the more academic objectives.

23. Jeske: Do you feel that the scientific processes are helpful in teaching of science, particularly for doing lab work?

24. Priestley: Yeah, they are important but for some reason, and maybe this is my own problem, I don't like the way I present them. I tend to do a unit on processes at the beginning of every year and the kids somehow feel that this is isolated from the work they are going to do in the future, especially so with the grade eights because the processes aren't so intimately involved in the lab work we do at the grade eight level. But at the grade nine level it is much easier, when they are writing up the experiment, just to have a series of steps to help you to organize and I tend to put it that way to them that they are not something unto themselves, to be understood, they are just a series of processes. Kids get so up tight in wanting to graph everything, or wanting to have inferences and observations and hypotheses, or a whole range of things, calculations, and they feel they must have everything to have a good experiment, well, they don't have to. Well, once they grasp the fact that they are just steps and you choose the steps that you need. A particular experiment, then they roll with the processes and they find them an assistance rather than a hindrance. So, it is just a matter of getting that across to them.

25. Jeske: Do you sort of progress in the number of scientific processes you give at each grade level?

26. Priestley: Yeah, I have sat down with the grade seven teacher and we have discussed which processes are most appropriate for grade seven. I do a review of those and then add some more at the grade eight level. At the grade nine level we cover them all I would say, with a very small emphasis on theory, developing a theory,

they find great difficulty with that.

APPENDIX N

INTERVIEWS OF SELECTED STUDENTS

SUMMARY OF INTERVIEWS WITH STUDENTS IN ARFVEDSON SCHOOL

Legend: (K) = Karl's response
(J) = Jacob's response
(O) = Olaf's response
N.R. = no response provided (student absent or topic did not come up during interview)

Laboratory Work is Concerned With Experimenting
(K) I think of stuff that has to do with chemistry, you are experimenting to try and find something out.
(J) So sometimes I think it is exciting. ....because of the experiments we do.
(O) Its going to be hard, experiments.

Feeling Toward Doing Laboratory Work
(K) You feel sort of curious, interested. You want to find out some new things, what certain things mean.
(J) I feel like excited and I just want to watch do it.
(O) I feel good about it, instead of always copying notes I can do some experiments.

Reading in Science
(K) A lot of the books are outlined very well. ....It is explained in great detail so that you can understand it.
(J) When I was doing this one I couldn't think of anything. So I picked up the science book and I started reading it and there were some words that were easy to read and some words that were hard to read, so I just put undecided.
(O) Is difficult because of all the words like potassium, permanganate, Benedict's solution and these different other things.

Too Much Time Spent Doing Experiments
(K) ......But if you conduct that experiment, you learn and you tend to think back to that, and you remember it better.
(J) We usually write notes and all that stuff, but not that many experiments.
(O) Well, we don't do enough experiments.

Studying Today's Problems in Science
(K) ......It is not really today's problems at least not in grade 7. It's just sort of an introduction to get into more serious work in later grades.....
(J) Like in the microscope unit that we did, we were talking about the past, with Aristotle and all of them.
(O) Most of the experiments deal with what happened before.

Enjoy Science Experiments
(K) ....It's nice to be able to find your own answers to a

question or a problem, rather than just reading it out of a book or being told.

(J) It makes me feel like a scientist when I am doing experiments. It makes me feel really good, and then I go home and tell my parents what the experiment was about.

(O) Well, they are interesting and not to hard to do. You learn about what different things do.

Solve Problems Better Than Before

(K) We took at the beginning of the year the scientific process and we have taken a few other processes where you have your problem and then you read up on the other steps and finally you are able to solve the problem. You make your own prediction, your hypothesis. I helps you then to solve your problems.

(J) When I was in grade six I knew lots but when I got into grade seven I still knew that, but there were some things that I didn't know. (undecided)

(O) (Undecided) In elementary school we never did any experiments.

Think About Things We Learn In Science When Not in School

(K) ...You refer back to it and questions come to your mind and you ask the teachers at school about them.

(J) .....when my mom was planting potatoes one day, I was telling her what happens when you plant a potato.

(O) Some of the experiments if I have the right stuff are tried at home again.

Want to Take More Science Classes

(K) Without having someone to go through the scientific processes and study things carefully, there would be a lot of discoveries that we have now, which are conveniences, that we wouldn't of had otherwise.

(J) ......When I look through the microscope I can see how it really looks, and so I like that. But, I still like chemistry though, it is fun to make things, it is real fun.

(O) Some of the experiment are interesting, and some are boring.

Science Is Dull For Most People

(K) Many people they may say that it is dull when they are reading out of a book, but then anybody can get bored after a while just reading out of a book. If you were to ask all the people how science was, and if some of them would of said it was dull, if they were reading out of a book. If you go in when they were conducting an actual experiment and ask how science was, then you would probably find that they all enjoyed science because they would be having fun doing experiments.

(J) ....We were having in class an argument about why we have to take science. The teacher was giving us an example, let's say you want a microwave. But one of the girls said I don't have to know what the microwave is about, all I have to do is press buttons and it cooks for me......

(O) They say why do you need science

Learn A Lot From Doing Science Experiments

(K) ......you can learn a lot more and it will stick with you by doing the experiments.

(J) When I was in grade six we took science, but we didn't use the microscopes that much. So I brought my microscope in and everybody kept coming over to my corner and wanted to see through it. I brought some onions, apples and that stuff and I cut them up. It taught me a lot about how it looked.

(O) There are experiments that I haven't even known existed. We try them in school and then I know how do do them.

Most People Like Science Classes

(K) As far as the lab work goes and conducting of the experiments, I think everybody is very interested in that, because it is fun to do those kinds of things. But, I think a lot of people make it boring for themselves. I think they enjoy science, but because they sit down and read out it out of a book or take notes quite a bit they find it quite boring. But, if it was all totally doing science experiments, just about everybody would call it very excellent and totally enjoy science.

(J) They don't like science, they don't like science classes because they think it is dull and you don't learn anything. .....I like science better than Language Arts.

(O) Some people say science class is boring, but then when they do experiments it is not.

Arguments Within My Lab Group

(K) Most of the time it is just straight forward. Sometimes there are mistakes. If you just go and yell at them and say that's wrong, then they take offense against that and try to defend themselves. But if you walk up to them, and maybe you can even draw a diagram or something, and show them politely and say I don't think that's totally right. But you don't condemn them then they will be more willing to accept that and then to redo it correctly.

(J) .....No, not really because they just don't care about science. So they don't get into arguments because they don't really have to.

(O) One says I want to do this, and another one says I want to do that.....one of us finally does whatever he wants.

Enjoy Working With Lab Partners

(K) I think it is most their cooperation, you fell good to be part of the team that's doing things right. And even when you do things wrong the others correct you properly.

(J) .....The lab partners I usually get are all friendly and kind and let me do what they don't want to do, and I do.

(O) Most of the time we disagree..... They just do the experiment and don't do the writing.

Pre-Laboratory Discussions

(K) In the books there is a lot of detail most places, yet it is sometimes difficult to take something out of the book and apply it to that which you are actually doing. We also have from other labs, out teacher told us the proper way to conduct certain lab activities. For example, boiling water and doing things slowly. And the teacher sort of coming back to this and reminding us, not only helps us to be able to me more united, as far as being able to get together by no one making mistakes. But it could also prevent some accidents that may happen.

(J) The teacher tells us what we are suppose to do and how. If he never told us, everybody would keep on making mistakes and keep on asking the teacher, in fact the whole class would have gone.

(O) If we didn't have the pre-lab then we won't understand what to do in the experiment.

Laboratory Experiments Should Not Have So Many Instructions

(K) ....If you start taking away from one, like in this case, maybe the instructions from the book or manual then you are also taking away from the quality of the work you will be doing.

(J) Well because the teachers explain it, and so they tell us, and then when we read the book we already know....

(O) With instructions it gives you more time to think about what you are going to do.

Teachers Help Students Too Much During Laboratory Activities

(K) This again depends on the kind of experiment that you are going through. And also it may be true that teachers do provide a little bit too much help sometimes because some kids tend to be a little bit lazy.....

(J) They don't provide us with that much help, because if they did and then when we are doing it ourselves we wouldn't know what to do......

(O) Teachers should help less so that you can figure it out yourself.

Open-ended, Unstructured Investigations

(K) .....I think it would sometimes be better to make you think hard and make you really try to find the answer. Yet it would also depend on what kind of experiment it was that you had to do, how complicated or simple it was.

(J) It would probably be fun, making the steps. Because if you did the steps yourself and it worked then people would want to know, and they would start copying and everything, and you would feel proud.

(O) Are more challenging.

Teacher-Student Laboratory Interaction

(K) .....Most of the kids they kind of feel good that the teacher in a way is trusting them by being able to walk around and not constantly watching them. Yet he is concerned with their safety by walking around and checking, and also trying to answer any questions they have.

(J) He should watch you and ask you how you are doing, what's wrong, or what's going on, or something like that. But, I don't think he should help you because then we won't learn anything.

(O) N.R.

Learning Science Concepts Without Laboratory Work

(K) You could probably learn them, not as well, but you could learn them. But it is almost like on the job training sort of thing where if you actually have your hands on the thing you are actually doing it, you remember it better and it makes you even more willing, more open-minded to learn because it is not boring.

(J) .....If you just get notes most of the times it just tells it and explains it to you and you don't really understand how it happens and everything like that.

(O) Lab work tells you what all these things do, it helps me to understand.

Provided Inference Questions

(K) They sort of follow up the experiment and it is good because it makes you review. It makes you think back to what you actually did do. So that it wasn't just some guy slacking off or whatever and was just having fun doing the experiment. That is probably the best part about learning-reviewing the work.

(J) ......I do like doing the questions, but not really writing it down.

(O) Don't like doing them, some of them I can't get.

Writing Lab Reports

(K) Well, everybody would probably say they enjoyed the questions better, there is less of them and they are not as hard. But, as far as the learning goes it is better to do the lab reports. The report is fully detailed and going over all the steps over and over again and sort of permanently impressing the scientific processes on you brain.

(J) ......laboratory reports are not bad, I like them better than answering questions. .....Answering questions get boring after a while.

(O) It's easier because questions you have to think for a while and if you don't get it, then you just don't get it. But for the lab report you just think of things and you write them down as you are thinking them.

Doing Laboratory Work Without A Partner

(K) ....But I find that as far as conducting the experiment it is nice to be able to work with other people. Some people you may not get along with, and that is not so good. But for the most part most of the kids really sort of get united and they work as a team to make sure that this experiment is conducted properly and that they can get the best possible results.

(J) Because like when you have some partners they like to bring you and things like that.

(O) A partner can help you figure out things. When you are alone you have to ask the teacher and he is talking with somebody else and so it takes longer to find out.

Would You Learn More By Doing Experiments Yourself

(K) ....I know myself I have been corrected for making some mistakes with the scientific processes that could have been fatal errors in my reports. Working with a group like that really helped me to change those ways and get to do it properly.

(J) Because you won't have to hesitate to do it by yourself. No one to bug you and make it harder to learn.

(O) No.

Most Investigations Teach You Something New

(K) .....There are sometimes when we have taken some experiments which were a little more difficult. But for the most part they are all pretty simple and you can easily pick out a good hypothesis.

(J) Some I know the answer for before I do the experiment and some I don't. So it is really even.

(O) They teach me more.

Doing Investigations For Which You Know the Answer

(K) Well, if you know the answer it is not very good because then it just takes out some of the fun of conducting the experiment. If you have absolutely no clue to what the answer is, then it also takes out some of the enjoyment or possible learning potential of it because you get discouraged.

(J) Well sometimes I don't really want to do it or anything because I know what is going to happen and something like that. So it isn't really fun doing it over again.

(O) The ones where you know the answer would be easier and it wouldn't take you as long.

Laboratory Work Improves Skills In Handling Equipment

(K) Now handling the equipment you know exactly what purpose the equipment has, how to use it, and what exact thing to use if for.

(J) Like the microscope, our teacher taught us how to handle the microscope.

(O) Yeah, just the other day when we did an experiment with the leaf, we put the leaf in water, then he said everybody has to put out the bunsen burner first before he brings out the alcohol.

Handling Unfamiliar Equipment

(K) Well, I had never seen a bunsen burner before the beginning of grade seven. And I felt very unsure until after the teacher had given us a full explanation of how to do it......

(J) Well, sometimes when we do that I get like kind of excited because I don't know what it is.

(O) I would feel nervous in case I break it or something.

Improvement in Observational Skills

(K) We are able to dig into the experiment for information, as well now we are more familiar with all the processes. Probably now we are getting into more complicated stuff because we are now able to take on these more complicated things. Where more and more of it is starting to be dependent on us and how we use the processes, the various scientific tools to our advantage.

(J) Because as time goes on you know you are getting better because you start looking at different angles and different ways until you really know it.

(O) Well, I've new done the experiments before and they are educating me.

Laboratory Partner Involvement

(K) ....Although it is enjoyable for me to do it, I wouldn't want to leave them out. I would like to give them a chance to try and to something too. ....

(J) No, everybody has a chance to become involved, but some don't want to, they just like fooling around. ......I think they shouldn't even be in this class if they don't want to do anything.

(O) I feel that they shouldn't be in the group if they don't do at least something in it.

Handing in Laboratory Reports For Marking

(K) Personally, because I enjoy this, and I am getting good marks in science, because of this I don't mind.

(J) I know that the teacher looked at it and he knows what I am doing, and how I am doing.

(O) Some of them I get wrong, and some of the answers are crazy.

Teacher Demonstrations

(K) It would depend on the class again. Like I said before, I enjoy doing the experiments myself and I can still sit through a demonstration and watch the teacher. But it would also have to be fairly interesting because I don't really enjoy watching someone doing a boring experiment all by themselves and you sit there and you are bored to death.

(J) These are good like the one about starch and we did one about a balloon.

(O) Shows me what is what, and helps me to understand the experiment better.

Level Inquiry Investigations

(K) I think I would rather do experiments that somebody else has already laid out.. It is interesting sometimes where you have to maybe make up your own experiments, where you can prove a point. But it is fairly difficult and it is better to stick to what someone else has devised.

(J) I like making my own experiments because I think it is fun. I've always wanted to know how to do experiments and stuff like that, as it would be interesting.

(O) Make up my own experiments so that I know what I am suppose to do.

Constructing Needed Apparatus

(K) Well, I enjoy working with my hands, like I like creating things from wood and everything.

(J) You would get a better idea of what you are doing how the thing you are using works.

(O) You know more of how it works and everything.

Everyday Applications of Laboratory Work

(K) Well, when we studied all the cells and everything it was interesting to note that whenever you walked past a living, or even a non-living thing, you sort of know what it was made of, or if it was dead how it used to work, and if living how it does work.

(J) No, not really, not that I know of.

(O) Like the clouds, they are different names for different shapes.

Laboratory Work As A Play Period

(K) ....I don't think lab work should be cut out either because for those of us that to pay attention and who do work hard on the labs, it is a very good part of science and helps us to learn better and remember better.

(J) .....But if you really wanted to do it and learn it and you started working then I don't know if it is a play period or not. To me it seems like a work period.

(O) They are not exactly play periods, but what they mean is that you can do all these interesting things. When you are working on the bunsen burner that's probably not a play period.

SUMMARY OF INTERVIEWS OF STUDENTS IN CHADWICK SCHOOL

Legend: (M) = Marie's response
(A) = Alfred's response
(I) = Irene's response
N.R. = no response provided (student absent or topic did not come up during interview)

Attitude Toward Laboratory Work

(M) I think it is interesting, it's fun, you learn a lot.
(A) Fun, it is a change from seat work.
(I) Doing lab, it's kind of fun.

Do In Class What Real Scientists Would Do

(M) Scientists probably would to these experiments because lots of things are in contrast with others....scientist of course use the scientific processes.
(A) It is a lot more basic here than what you think a real scientist would be doing....scientists probably use the scientific processes in their work.
(I) I guess there are so many different kinds of scientists, and its to general we do lots of stuff not just one specific thing. ....I think they do use the scientific processes.

In Class We Study Today's Problems

(M) Lots of people, lots of scientists, have repeated studies that have been done many years ago, and they do ones that they feel will be done in the future, and we do them from all groups.
(A) We don't go to study what somebody has already done, sort of thing.
(I) We study things like, how do minerals form, but really that has nothing to do with pollution, or whatever.

My Friends Enjoy Science Experiments

(M) Most of my good friends thing science experiments are fun. They think they learn a lot too, they enjoy them. Some of my friends might say this was neat, or that's fun.
(A) Usually when I ask my friends if it was good, enjoyable, they say agreed.
(I) Well, I enjoy it but some people don't.

Everyday Applications of Laboratory Work

(M) Some people think that science is just lot of lab work and things, when you can go outside and look at leaves and things.
(A) No, not really, because the things I have to do at home don't really have anything to do with what we do here.
(I) N.R.

Taking of More Science Classes

(M) I guess there is so much science that you can take. I would like to learn about all kinds of different things. I enjoy all my other classes too, so I wouldn't want to make an uneven choice, but keep a balance.

(A) ...I guess it really depends on my work.

(I) I find it kind of hard to understand, all the science to remember. I really don't want to take that in university, that's not what I want to do.

Reading Science Is More Fun That It Used To Be

(M) In elementary school we only did some simple experiments, and we used to read a lot than, but now we get into more complicated things, so it is more interesting.

(A) I sort of decided this one on my elementary. They sort of haven't changed things except use more complicated equipment at this level than they did in elementary.

(I) It is more difficult, a lot more difficult to understand, at least for me.

Science Is Dull For Most People

(M) Everyone, even if they think they don't enjoy science, probably they do, because there are lots of areas of science and they are all different, they may think they are not doing science but they really are.

(A) Usually when we are in science, no one is falling asleep sort of thing.

(I) There is a lot of seat work, and that's pretty dull, just sitting there talking back and forth. The only interesting part is the labs.

Laboratory Experiments Should Not Have So Many Instructions

(M) I think it is better to have students do all the work, so that they learn and it is not all done for the, so that they experience how to do it and learn.

(A) I like it how it is sort of thing. There is usually room for friends to day what if they didn't work this way, you can think about it in your own mind sort of, in perspective.

(I) Strongly disagree, it is hard for me to understand.

Post-Laboratory Discussions

(M) It would be a waste of time if you went out and spent the time on participating in an experiment, why bother to do it if you are not going to put some effort out to discuss it.... If you didn't understand something that was going on in an experiment, discussion with other people saying things may help you understand it more.

(A) Class discussions after the experiments are helpful. Probably it gives you even a clearer picture of what all the lab work is about, and it give you sort of a greater understanding of it.

(I) It is reviewing it sort of and pointing out stuff you wouldn't of thought about by yourself, unless you really thought hard about it.

Teachers Provide Students With Too Much Help

(M) You can't just go and do something by yourself, you need some guidance. I don't think you can be expected to know everything right away. You need some help and guidance.

(A) N.R.

(I) sometimes the instructions are unclear and you don't understand them too much.

Reading Science Is Difficult

(M) If all depends if the concepts are thoroughly laid out, in that case it is quite easy to understand it, and you can easily grasp the concepts..... In most cases all of the experiments we do are mapped out for you and ordered first.

(A) Sometimes it is pages and pages of information.

(I) I am not interested in it really. If I wanted to be a scientist than I would probably really get into it, and try really hard to do good work. But, now I just to what is assigned and no more.

Involvement In Performing Laboratory Experiments

(M) I like to participate because I feel it is an important effect in your training.

(A) lIt is interesting most of the time, and it is sort of neat to find out things which you have never known before.

(I) I guess because I'm not interested in being a scientists. I like doing the labs and stuff. Oh, I guess I just classify it as another school thing. I just do what is assigned, you don't have to get like happy about it, sort of just do what is expected.

Working With Lab Partners

(M) Last year I didn't have the same partners, and I didn't quite enjoy it last year because I was put with a person who didn't l;like to take part most of the time. But, this year I have a friend, and she likes to work in experiments just as much as I do.

(A) ....My lab partner does basically the same amount of work as I do, and we are equal sort of thing.

(I) ...So this way we can help each other without being totally brushed off... We are not best friends but we are not bad friends, in other words, we just get along good.

Pre-Laboratory Discussions

(M) It will help you if you discuss before you actually take part. It will also help you to understand what you are trying to get at, and what you are trying to find, or it will help you to understand it more.

(A) ....It gives you a clearer picture of what you are do do, and what basic outcomes to expect.

(I) It's more instruction even if the teacher is going over the lab notes. ... well I would have trouble doing the lab. The teach can show you what to do.

Read More Science Than In Sixth Grade

(M) In elementary school I guess you wouldn't have such an intensive course because you are in a lower grade. You wouldn't think that would have anything to do with it, but when you progress you study more.

(A) Most of the experiments now are more important and they are more knowledge gaining than in grade six.

(I) I don't understand stuff about science .....

Laboratory Work Helps To Understand The Concepts

(M) ....you get to experience lots of things that you won't normally do.

(A) Most of the time I don't understand it completely without doing the lab.

(I) You can see it happen sort of and you can understand it better because it is right there in front of you.

Laboratory Reports

(M) N.R.

(A) You are making use of your mind, it makes you really think quite hard.

(I) .... Like you can do a lab and just do what the instructions say, but when you write a lab report you have to think it out.

Doing Laboratory Work Without A Partner

(M) One partner can't do all the work. It's fun to have a part in the experiment, be an important part.

(A) Sometimes you need help with something.

(I) Well it cuts down on the work, like if one can hold the beaker of water and once can weigh it and stuff like that. If you don't understand something, maybe your partner does.

Most Laboratory Experiments Teach You Something New

(M) Sometimes it will lead to that, so that you know what you are trying to find, and you know exactly what will come about in your experiment. It is always nice to try it anyway to see if that's what you actually get, or if you have done something wrong.

(A) For instance, we did an experiment in sugar refining, and I didn't know that you can transform the color of brown sugar into white sugar. It taught me how it does it.

(I) You don't really understand relative density, or don't understand that relative density is such and such. But with lab experiments you do it and prove it to yourself.

Inference Questions

(M) N.R.

(A) Well the labs are more realistic and you can only tell what it is really like, sort of time, when you do lab reports.

(I) With questions you've got to be specific and you have to be right, but with lab reports you can sort of put what you want.

Laboratory Work Improves Manipulative Skills

(M) It does because you get more experience on how to handle these things and you become a professional in your own right.

(A) It teaches me how to use equipment more wisely and more cautiously.

(I) I would think so.

Teacher-Student Interaction During Laboratory Work

(M) When you have a problem and you really don't understand it, and you are having a hard time the teacher should be there to explain it to you when you are really stuck.

(A) N.R.

(I) I think it would be better just once, to come around and see what is happening. Just to make sure you are doing it right.

Laboratory Work Improving Observational Skills

(M) You can recognize, say if you have done an experiment and then you see it in a book, you really see it. You would recognize it right away if you have done the experiment before, rather than just looking at a book picture. I would rather actually do the experiment myself and be able to recognize it and learn more that way.

(A) You learn that in grade 7.

(I) You learn to look for more things, well you just learn to think about it.

SUMMARY OF INTERVIEWS OF STUDENTS IN ASTON SCHOOL

Legend: (N) = Nicolas's response
(R) = Rachel's response
(E) = Elaine's response
N.R. = no response provided (student absent or topic did not come up during interviews)

Attitude Toward Laboratory Activity

(N) Doing experiments, its fun, I like it. ....Yeah, I really like to do lab work.

(R) I like doing experiments, the fun part of science is experimenting.

(E) When I hear it I think of experiments, working out new problems, figuring out answers. It's o.k.

Do In Class What Real Scientists Would Do

(N) Well, just mostly working with the bunsen burner, and chemicals and stuff like that is the same thing.

(R) I don't really know what real scientists do, I don't know exactly what they do.

(E) Sort of it is, and some of it isn't. It depends on what we are work on.

Study Today's Problems

(N) Some thing like you know famine, and stuff like that, we study certain things and try to do something about them. We study how to make water and components to help people.

(R) Agree, because we do things on atoms, because we are still doing things with atoms in science.

(E) Most of the stuff is dealing with today.

My Friends Enjoy Doing Science experiments

(N) My friends don't really like science that well. They just aren't very interested in science. They think it's o.k. using and lighting a bunsen burner and that's about it.

(R) ....I don't really know, they don't really tell me. They don't seem to mind doing it, ...but I have never really asked them if they like it.

(E) They seem to enjoy working with each other.

I Think About Science Outside School

(N) All my friends are always make smoke bombs or something or other. They were trying to figure it out. So one time when they were trying to make a certain smoke bomb I told them to use some alum and other things I always used.

(R) I do think about a lot of things. My sister is studying to be a teacher and I always ask her questions about it. I always ask her about atoms and things like that.

(E) Maybe some I do, but I think most of it just related when we are in the science class. I don't usually talk about these things to friends, about science.

Want To Take More Science Classes

(N) You cannot just learn the basics, but need to learn more to use the basics, about atoms and how to make compounds and things like that.

(R) Well, I like doing experiments. I liked it other years when we dissected frogs and things like that. It interests me.

(E) Some of it I enjoy doing, but other stuff is o.k., but I would rather not do it.

Reading Science Is More Fun Than It Used To Be

(N) Before is was so laid out for you. You just had to read and that was it. It didn't explain anything that you heal with. Now you can read it and understand what they are saying

(R) I didn't really like reading science better before. I don't think it is more fun than it used to be. It is just harder, more difficult now.

(E) Because we are learning more.

Science Is Dull For Most People

(N) My friends, they think its dull, they fall asleep in class. When they go to high school they won't even take any more science classes or anything.

(R) I don't really know what other people think about science. Sometimes they like it too, they say "that was fun". What we just did was fun. But, sometimes they don't like it.

(E) A lot people enjoy science and some people don't. It just depends on the person.

Doing Lab Work Without Getting Into Arguments

(N) If everyone is doing something, either pouring something, lighting something, or doing something they always have fun. So one person is just not sitting there dosing off.

(R) The people I work with, I sit beside. We all get along well, we all have fun. They are smart and I learn a lot from them.

(E) Someone is doing the experiment or whatever and they mess it up, then everyone gets mad at that person.

Laboratory Experiments Should Not Have So Many Instructions

(N) If you have everything done for you than you don't have to waste time making and doing everything first. So you can figure it out and get right into doing the experiment. .....I like to try something new every time and not know automatically what we are doing. I like to figure it out, and find out what you are suppose to do. ....Just walking in and knowing how to do it is not a challenge.

(R) It;s harder, we don't have enough time really to figure out all that stuff in the 40 minutes that we have. It's easier when we have all the instructions.. I need help to catch on to what I have to do.

(E) Agree, if everything is there for us, all you do is follow that and do the experiment. But if you have to dig up the information for yourself it takes a little more thinking about what you are doing.

Post Laboratory Discussions

(N) You might just do it, do your experiment, and right after you finished don't talk about it, and don't do anything, then you just forget about it. So if you go right through it again you will fully understand what you are doing.

(R) You learn a lot from doing it, like just from the questions after. It's just that you learn a lot from it.

(E) If we did the experiment, and someone doesn't understand what is happening, then if we take time in class to discuss what happened, why it happened, it helps them.

Teachers Provide Student With Too Much Help

(N) I don't mind the teacher telling us, like today he put a little more iron in there, I don't mind that because you want a successful experiment. You don't want to goof up, so it is good for the teacher to tell you what to do, and to a certain extent that is helpful to you.

(R) We only have one teacher, and he can't be with everyone at the same time. Often I need help but he is with another student or something.

(E) Well, teachers actually don't help enough. They give us the sheet, we read it over. Usually there are too many people in the class, and the teacher doesn't get around to everybody. So if you don't do it right that causes you not to understand what is happening. So if the teachers may be took more time to try to get to everybody.

Teacher-Student Interaction During Lab Work

(N) I don't mind it to a certain extent, as long as they don't come in there and do it for you. ....I wouldn't really mind as long as the teacher isn't just there to bug you or something.

(R) Because if I am doing something wrong I want to know. I don't just want to go, oh that's o.k. I want to know and I want to correct it.

(E) The teacher should come by to make sure we are doing it right. So that we are not messing it up as we are going along. If so, then he can stop us.

Doing Laboratory Work Without A Partner

(N) It is better to have more than one person, so that you can have their input and find out what they think. You learn from other people and what they are thinking, I helped one guy just a little while ago.

(R) I wouldn't know what I was doing. It's just because with partners there are people there. If I don't know it, they might. It's just easier.

(E) If we get stuck we can talk to each other, talk to each other and get it figured out. If I had to do it myself it would be harder.

Laboratory Experiments Teaching You Something New

(N) No, its not something that been given before.

(R) Once I do them then I know the answers, but otherwise I don't unless I see them. ....I Well, we had to do it in another period, to finish the experiment. And at the end of the first period, we kind of thought we can't wait to see what that is.

(E) Most cases it is something new. Some I have heard before, and some the teacher explained.

Lab Reports Against Inference Questions

(N) I would rather do a lab report. The questions are doing most of the thinking for you. They are asking you the questions and hoping you don't get the answers.

(R) It's not that bad, it doesn't take that long or anything. You just have to remember back to what you were doing before. ....Lab reports are easier because it comes from you, like you write down what you think. You write down what you know, and in the questions you don't understand it all. It is easier when you do lab reports because you know everything you are writing.

(E) In lab reports you think about what you are doing and have to go back and remember everything that happened and that you wrote down. If it is just written out and we follow by it, then it is not as fun as if we have to do the work ourselves.

Laboratory Work Improves Manipulative Skills

(N) N.R.

(R) It is like using the bunsen burner, you could burn yourself or something. But as you use it your learn not to touch it, you know how to use it better. You are more careful with things because you know it can hurt you.

(E) Yeah, ...he trusts us enough to let us handle the stuff and not break it.

Improvement In Observational Skills

(N) N.R.

(R) You have to watch it more, like you always have to write down observations and things. So you really have to watch what is happening.

(E) Yeah, I am more interested in it now then I was before.

Open-ended Investigations

(N) You have the problem of extracting a whole bunch of components, it is more exciting. You had to do a lot more work, it dealt with something more significant. I had to do a whole bunch of things just to find one thing.

(R) It is a challenge, its a challenge because you have to learn for yourself. You have to figure out the different ways of doing it. ....It comes in the middle. If the teacher gives me an interest one then I would like to do it. But it is just as easy, I can do my own, make my own experiment.

(E) It is more challenging, get more of a chance to show what we can do..... You have to try and get everything out of it, identify it, like we didn't quite know how to separate them. So we had to figure out ways on our own, from those that we learned before, bring them all back and figure each out.

Requiring Teacher Assistance During Open-ended Investigations

(N) No, just to find out what some of those components were and stuff like that.

(R) More, a lot more. Because we couldn't figure out something ....I asked him to come over and help us a lot.

(E) It wasn't hard, it was quite easy. We did require the teacher's help in order to identify some of the stuff, but that was it.

Requiring Partner Assistance

(N) We helped each other.

(R) I did a lot of the work, because everybody else kind of shied away because they didn't know whether they were doing it right or wrong. So I just sort of did a lot of it. I said lets do this, let's try this and see how it works.

(E) We just worked together on it. ....we worked it out within the group as that helped to explain things.

Prefer Doing Experiments Over Demonstrations

(N) I would rather do it myself because I get more out of it. I'm thinking more about what I'm doing. I'm doing it and learning about it, instead of just watching what is going on.

(R) I like to do it by myself because you do learn more than watching someone. Like you are not really watching how much they are putting in and everything like that. This way you have to make sure of the exact amounts and everything, its better.

(E) N.R.

Constructing And Assembling Apparatus

(N) ...most people think those things are given to us, to help us. But when you make them they always sudden become something else. You find out what they are and what they are suppose to do.

(R) It depends how long we have to do it in, if we had a long time then it wouldn't be a problem or anything. It would kind of be more fun.

(E) N.R.

Everyday Application of Laboratory Work

(N) ....To a certain extent, there are lots of places, you can just see a whole bunch of things.

(R) Like when we did experiments, by putting things over the bunsen burner and the colors (flame tests). Something like that, this happen quite often.

(E) N.R.

Laboratory Work As A Play Period

(N) To put it nicely I would say to them you don't know the difference, you just think it is play.

(R) I guess people might take it that way, even people that are doing them, because it doesn't really seem like work. It seems like a lot more fun than it is work, but you learn a lot from it though. So I guess you could say it is both, but I mean the people who are doing it don't play. Just because it's neat to watch, I don't know, it's just that way.

(E) N.R.

Involvement Of Laboratory Partners

(N) I like to have everybody doing something, putting their thoughts into it.

(R) In our group everybody gets about the same amount of time, unless somebody is just not working. I don't think there has been a case where someone has sat around. But, if they are away for a day they may sit and watch at first to see what is doing on.

(E) N.R.

EXAMPLE OF A STUDENT INTERVIEW TRANSCRIPT

1. Jeske: What comes to your mind when you hear someone say school science laboratory work?

2. Rachel: Mostly experiments, yes experiments.

3. Jeske: How do you feel when you hear that?

4. Rachel: I like doing experiments, the fun part of science is experimenting with a whole bunch of things and learning about them.

5. Jeske: You don't say, oh no! Experiments again?

6. Rachel: No, I like them.

7. Jeske: Now on your paper, question #4, "What we do in class is what a real scientist would do" and you put down undecided . What were your reasons for giving this answer?

8. Rachel: Just, I don't really know what real scientists do, I don't know exactly what they do.

9. Jeske: So you are sort of unfamiliar with what scientists out there do, unfamiliar maybe because you have no connection to them.

10. Rachel: Yeah.

11. Jeske: Question #5, "In science class we study to-day's problems" and you put down agree, why do you agree with this statement?

12. Rachel: Because we do things on atoms, because we are still doing things with atoms in science.

13. Jeske: Can you ever take what you learn in science and solve some of the problems that your mother asks you to solve around the house. You say I don't know how to do this, and then you think back, oh yeah science.

14. Rachel: Sure.

15. Jeske: So you can apply your science in real life?

16. Rachel: Yeah.

17. Jeske: Question #10, "My friends enjoy doing science experiments" and you said undecided . Why did you say this?

18. Rachel: Well my friends in my class, I don't really know, they don't really tell me, they don't seem to mind doing it, but in the other class I don't know. They don't mind but I have never really asked them if they like it.

19. Jeske: When you are working with them what do you see?

20. Rachel: Yeah, I guess they do like it.

21. Jeske: more than just sitting there reading a book or listening to the teacher.

22. Rachel: Yes, more than just doing work sheets or something like that.

23. Jeske: Question #12, "I think about things we learn in science class when I'm not in school," and you put down agree . Could you tell me more about this?

24. Rachel: Yeah. I do think about a lot of things, my sister is studying to be a teacher and I always ask her questions about it. I always ask her about stars and things like that.

25. Jeske: Question #13, "I do not want to take any more science classes than I have to take" and you put down disagree . That tells me you want to take more science courses. What are your reasons for saying this?

26. Rachel: Well I like doing experiments and I liked it other years, we dissected frogs, and things like that, it interests me.

27. Jeske: You like biology then?

28. Rachel: Yeah.

29. Jeske: Question #14, "Reading science is more fun than it used to be" and you put down disagree . That tells me you liked reading science better before.

30. Rachel: I didn't really like reading science better before, I don't think it is more fun than it used to be. It is just harder, more difficult now.

31. Jeske: Question #16, "Science is dull for most people" and you put down undecided . Could you give me your reasons behind this answer?

32. Rachel: I don't really know what other people thing about science.

33. Jeske: When you talk to your friends, in general, do they say, oh science, I don't want to learn that junk.

34. Rachel: Sometimes, but sometimes they like it too, they say "that was fun". What we just did was fun. But sometimes they don't like it, when we read or do work sheets they don't like it.

35. Jeske: Would a lot of the students rather be in science than lets say language arts?

36. Rachel: Probably.

37. Jeske: I'm not saying this in reference to the teachers, but with respect to the subject.

38. Rachel: Yeah.

39. Jeske: Question #23, "The members within my lab group do the labs without getting into arguments" and you said agree . Could you tell me why this is so in your particular group.

40. Rachel: The people I work with, I sit beside, we all get along well, we all have fun, they are smart and I learn a lot from them.

41. Jeske: Have you ever worked within a lab group in another grade where that wasn't so?

42. Rachel: Yeah, last year, I didn't really like some of my lab partners.

43. Jeske: Question #27, "Laboratory experiments should not have so many instructions in order to allow students to think more about how to do the experiments." So rather than having them all laid out with the background information, materials listed, inference questions given and so on, rather give the students a problem and let them do the rest of the work. Your answer to that was disagree . That tells me you would like more structuring. Why did you say this?

44. Rachel: It's harder, we don't have enough time really to figure out all that stuff in the 40 minutes that we have. Its easier when we have all the instructions.

APPENDIX O

SUMMARY OF PRE- AND POST-LABORATORY DISCUSSIONS

SUMMARY OF PRE-AND POST-LABORATORY DISCUSSIONS

At each grade level the pre- and post-laboratory discussions are summarized under appropriate discussion headings. This is done for each investigation observed. It was very difficult because of scheduling and classroom routines to tape post-laboratory discussions. Post-laboratory discussions for many of the investigations observed occurred after the researcher had left the school and was scheduled to be at another school. This was even more predominant because of being scheduled in each school for two separate blocks of time. In addition, whenever teachers took in laboratory reports for marking the post-laboratory discussions occurred after the reports were marked. In most cases this again happened after the researcher had left the school. The pre- and post-laboratory statements included in the summaries are numbered, these numbers indicate from which investigation the provided statement has been taken. In case of the post-laboratory discussions, the absence of a summary indicates that none were taped.

Grade 7 Class

Pre-Laboratory Discussions

Directions for Writing-Up the Experiment

(1) ....we are going to write down our problem, and we are going to write out the title. ...you will also write down the purpose. What we are going to do is test for the presence of glucose. The reason we want to test for glucose is that we want to prove that there is sugar present in a plant.....

(2) Write down the title. "When Do Plants Contain Starch." ...we always write down the purpose: To determine the effect of light on the presence of starch in leaves.

(3) I want you to draw on a piece of paper the cross section that you see under the microscope of both of these.

Review of Previously Learned Concepts

(1) We found in our introduction (worksheet) that the way the photosynthesis process works is that the sun gives off energy, strikes the green plants, activates the chlorophyll in the chloroplasts. Inside the chloroplasts the chlorophyll is activated by the sun's energy and with carbon dioxide and water produced sugar and oxygen.....

(2) This is corn syrup. For what substance did I test corn syrup? Student: glucose.

(3) Does everybody remember the sequence in making a

slide?

Explanation or Demonstrating of Procedure for Performing The Investigation

(1) ....We are going to take three or four pieces of the green plant, we are going to place it inside of a test tube. We are going to put in just enough water to cover those green pieces of onion, we are going to take 3 or 4 drops of Benedict's solution and place it inside the test tube. We are then going to warm the test tube over a bunsen burner. .....

(2) ....I want to prove to you first that we can do a test which indicates the presence of starch. The simple test for indicating the presence of starch uses iodine..... This first one is flour. ...and we get a positive test for starch because the iodine turns black. ...The next substance is ivory laundry starch. ..This is the first step where I will have a test tube of alcohol. There will be a beaker placed on your desk. You are going to take the leaf and swirl it in hot alcohol. The alcohol will also be sitting in a larger beaker with hot water in it. The only time you are going to light the bunsen burner is when you are going to boil the water with the leaf in it. The alcohol is not coming out until after we have boiled the leaf in the water for 3 minutes. You are going to have to work efficiently to do this.

(3) What I will do is give you some prepared slides to look at first.... Put the microscope on low objective first and focus, then to the middle power objective and then to the higher power objective.

Altering of Equipment or Materials Listed for the Investigation

(1) ....we are not going to use these clamps (test tube clamps) because they are very weak. ...so what we will do is use these clamps (utility clamps)...

Safety Precautions Indicated

(1) ....you never point the test tube towards yourself or anybody else.

(2) We cannot have alcohol in the room with lit bunsen burners. This is because of what? Student: Because it is flammable.

Development of Observation Charts

(1) I want you to make a small chart (teacher puts chart on board).

(2) Copy down this little chart (chart put on board by teacher).

Indicating Location of Needed Equipment

(1) I want the test tubes which are right here (on side counter) to be rinsed out before you use them. ... the bunsen burners are under each lab counter.

(2) You are responsible for setting up the bunsen burner, setting up the stand, and boiling the water. The iron rings are up there (on counter) and the pads for heating your water are in the first drawer. ... the beakers are in the cupboard.

Providing Students With Background Notes

(1) Benedict's solution with heat in presence of sugar will turn from a blue color to reddish orange.

(2) The starch test: When brown (light brown) iodine is placed on starch, the starch and iodine react turning the starch black. This is due to the reaction of iodine with starch.

Grade 7 Class

Post-Laboratory Discussions

Teacher Reads Provided Inference Question

(1) Question number eight: If the white part of the onion contained sugar, how do you think it got there?

Teacher Calls Upon Student to Provide Answer to Question

(1) Student: By photosynthesis.
Intern Teacher: Not right.
Another Student: (called upon by the teacher) By the process of diffusion.
Intern Teacher: Right.
Intern Teacher: (Repeats answer so that students can write it down if necessary). By the process of diffusion from the green part of the onion.

Student Doesn't Have Work Completed

(1) Question: What evidence did you find that shows that glucose is able to pass through cell membranes and move to different parts of the plant?
Student: I didn't get it, but I can guess.
Teacher: If it is a good logical guess then let's hear it.
Student: By osmosis.
Teacher: That was a good try, but that is not the answer.
Another Student: (answer to question) When you heated up the Benedict's solution the onion parts, either the white or green, the glucose kind of diffused out of the onion into the Benedict's solution.

Teacher: O.K., which caused?
Student: Which caused the Benedict's solution to change color.
Teacher: ....Now let's write this up, this is the answer you want to put down. The evidence that you find that shows glucose has passed through cell membranes and moved to different parts of the plants is that we have a positive test for glucose. ....

Teacher Provides Further Explanation

(1) The bulb of the onion does not contain any green material, in other words it does not have chloroplasts containing chlorophyll. Therefore, we know that the white part of the onion cannot produce its own glucose. The bulb is also underground where it cannot get sunlight. The only part which is green and contains chlorophyll is the green parts. So somehow you know that the glucose has to travel from the green parts of the onion down to the white parts of the onion. .....

Student Didn't Understand and Asks A Question

(1) Student: Why can't the white part of the onion produce glucose?
Teacher: It does not contain chlorophyll and therefore cannot produce sugar.

Grade 8 Class

Pre-Laboratory Discussions

Directions for Writing-Up the Experiment

(1) For this lab you are going to do lab reports. I want to explain right now what I want you to do. ...Do your usual hypothesis, variable identification, precautions, statement of materials, and that kind of thing. One precaution, find three controlled variables. The big part of this lab will come under data and observations as usual.... For inferences what I will have you do is just write a short paragraph after, telling what you have found. In other words, a response to your problem.

Review of Previously Learned Concepts

(1) Something else that you should know, and this you need to remember: 1 ml of water has a mass of 1 gram.

(2) Now briefly, its been a few days since you worked with this; What is the formula for relative density? ... All you need to do is hang the mineral sample from the string after the balance has been zeroed, and then balance it out and that tells you how much it weighs in air, ...

Explanation or Demonstrating of Procedure for Performing the Investigation

(1) What you will do is set the triple beam balance so that this end is over the edge of the lab table. ... there is a little sort of lever under the pan, what you do is connect the copper wire around there. ... To zero balance you turn this knob back here (shows students knob on the balance). For obvious reasons you know this is called a triple beam balance, it has three beams. We call these things riders, each one is calibrated differently; 100g, 10g, 0.1g. When we say to zero the balance what we mean is turn the knob, with all the riders to the left, until the pointer points to zero. ...what you have now is the mineral hanging from the balance. What is going to happen when I put this on is that the beams are going to go down and this pointer will no longer be on zero. That's why we call it a balance because what you do is balance it out. Start with the largest rider, o.k. At 100 it doesn't even move it, now if I move it to 200 it is too heavy, so I know the weight is somewhere between 100 and 200. So I can put the rider at 100 and then start moving the 10 gram rider until I get nearly balanced....so what you need to do is come up under the mineral with the beaker of water. Make sure the mineral doesn't touch the sides or bottom of the beaker because you will be pushing on it, and will effect what you read off of the balance.

(2) Now you won't finish performing the experiment today, that's fine. I would rather have you get good results, because if you are off by a lot the mineral identification charts won't do you any good.

Altering of Equipment or Material Listed for the Investigation

(1) In your notes, I want you to change the mineral numbers from 6, 18, 9 to 26, 3 and 25. .....I think instead of using the wire we will use string.

Safety Precautions Indicated

(1) But don't set the balance over the edge of the table so far that it will fall.

Development of Observation Charts

(1) This lab comes under part A and B, so part A is what we are looking at now. The chart that you will do for that I will show a shorter version of here (teacher draws a chart on board)..... A lot of people are losing marks needlessly because they are not following the rules, put a title on your chart.

Indicating Location of Needed Equipment

(1) I will set the mineral samples on the side counter by the curtains, and what I need is one person from each group to report to me to get a beaker and a piece of string. The triple beam balances are under your counters in the cupboards.

(2) I put string in the tote trays, at the end of the period would you please try and get it off the balance.

Providing Students With Background Notes

(1) I would like to give you two different formulas and examples for finding relative density which we will actually use in the lab.
The first formula is:

$$\text{Relative density} = \frac{\text{weight of object in air}}{\text{weight of an equal volume of water}}$$

Let's just do an example now...

Providing Students With Practical Applications

(1) Dalton: You don't actually lose weight, but the water pushes you up and you appear to lose weight. What do we mean by weight loss in water?

Student: How much lighter you are when in water.

Dalton: When you go into the swimming pool it is easy to lift up another person because there is a force called the buoyant force acting on you and it counter acts the force of gravity which is weight.

Giving Students Additional Practice Problems

(1) I'm going to give you some relative density problems before we do the lab, because I want to make sure you understand what you are doing. ....Let's just do an example now. Write the problem down and then I would like you to try and work it out. I'll make the number easy to work with (problem is written on chalk board). .....on the back of the page on relative density in your notes, there are some problems, do these. I also have 7 problems here (on a worksheet to be handed out) which I would like you to try if you have finished the other work.

Grade 9 Class

Pre-Laboratory Discussions

Directions for Writing-up the Experiment

(3) The last experiment in this series is not written up for you, you have to write it up yourself using all of the processes, or as many processes as are appropriate to use. ....you work in your groups

for this; however everybody will hand in a completed lab report. You will write it up the way it should be written up. .....So I will give you the problem: Separate and identify as many components (substances) as possible from the mixture.

Review of Previously Learned Concepts

(1) I am going to review lighting the bunsen burner with you because that can cause great problems. The main gas valve is down here, and I usually like to control that one. You have another gas valve on the table. .....When you are lighting the bunsen burner have the air-port valve closed. .....It first of all burns with a yellow flame and when you open the valve it turns to a blue flame. .....it is an extremely hot flame....

Explanation or Demonstrating of Procedure for Performing the Investigation

(1) So there are 7 different chemicals here. Each group takes one container, performs the flame test, and returns it. Don't try to hog two or three because some groups will be without any. ....It give you a point by point blow of what you have to do.

(2) In to-day's experiment you will get some sulfur and iron filings. You need to follow the design step by step. If you don't follow it step by step you will get fouled up.

(3) What I am going to do is give you a mixture. I am not going to tell you what is in it. Some of the things in it you have come across, some you may not have. You can use the techniques you have used for separations to separate them. It is not just a matter of separating them, but also trying to identify what the materials are. ....Just a word of caution, some people take this sample and immediately dissolve it in water, well once you have dissolved it in water you may have made it so that it is very difficult to do other things with it. For instance, if it is wet it is very difficult to screen it through a screen, or to do a separation by magnetism with it.
So I would suggest that you do all of the separation techniques that require it to be dry, do them just, or divide your sample into a number of different parts..... So you are using different parts of your sample for different techniques. ...I will give you your samples.

Safety Precautions Indicated

(1) Someone who cannot abide by the rules of safety will have to sit down and watch the experiment being performed by other people. Safety things with which we are concerned with in our experiment are toxic

chemicals. ....The other thing, is the bunsen burners can cause very severe burns by carelessly reaching across or putting your head over it. ...Over here is an asbestos blanket that can be use to extinguish fire on a person. ....Prevention is the best course of action. ...Don't attempt to taste the chemicals, I am sure you won't. But if you get some on your fingers and then put them into your mouth, you'll have to remember to keep your fingers away from your mouth. In fact try not to get the chemicals on your hands because some of them are absorbed through the skin.

(2) When you heat sulfur it gives of a smell. ..So we will heat the iron and sulfur in the fume hood at the back of the room, we will have a bunsen burner set up back there for you to use.

Development of Observation Charts

(1) The observations are recorded in the chart provided, you may not get them all done this period, but that's alright.

Providing Students with Background Information

(1) We will just read through the background information. It gives you an explanation of why it is that materials burn with a different color, basically every element has, or gives, its own color. ....

(2) An element is a substance made up of the same kinds of atoms. Give me some names of elements. Student: iron, oxygen, and copper. ...(teacher writes on chalkboard) An element is made of one type of atoms, and a compound is two or more kinds of atoms combined. Give me another example of a compound. Student: Water. What is that made of? Student: hydrogen and oxygen. What about a mixture, what would a mixture be? ....Can you tell me then the difference between mixtures, taking these examples, and the compounds we used last day....

(3) First of all number one: decantation (teacher writes word on the board). Decantation that is pouring off. When can you use that? Student: Taking cream off milk. So generally anytime one material is floating on top of another. Another one is sublimation (spells the word for students). Sublimation that is changing from solid to gas, or gas to solid without going through a liquid stage. Example. Dry ice changing to carbon dioxide gas. ...I have another example here, I am going to take some iodine crystals, and put a few crystals in a beaker, so that is a solid, (teacher heats the beaker which is covered with a watch glass). A vapor is forming, the solid is changing to a gas, in a few minutes the gas will sublimate again. ....

Providing Students With Practical Applications

(1) Different companies use different chemicals to make up their paints so that police can identify cars by doing color spectrum analysis of the paint chips. The paint is burned to identify what type of car the paint chips came from.

(2) .....Remember a couple of Christmas's ago the Lodge Pole oil well blew up and gave a smell around the school, this smell was hydrogen sulfide, a poisonous gas.

Grade 9 Class

Post-Laboratory Discussions

Teacher Reads Inference Questions

(1) Do copper chloride and sodium chloride give the same color flame? If not which element produces the color?

Teacher Use the Chalkboard for Explaining Question

(1) Copper chloride, CuCl, 2 kinds of atoms in copper chloride, copper and what else?
Student: Chorine.
Sodium Chloride, NaCl, sodium and chlorine. The copper burns green and sodium burns yellow. Now they are asking you whether the copper or the chlorine is giving the color?
Student: Copper.
.....If chlorine is giving the color then it will be the same color in copper chloride as in sodium chloride. Chlorine wasn't giving the color. So the copper and sodium are giving the color because chlorine is common to both compounds, so its color should be common.

Student Asks A Question For Further Clarification

(1) Student: Why can't it be a combination of both? A combination of the color of copper and color of the chlorine.
Teacher: Well, if you want to prove that you could try copper oxide and copper something else in the flame test.
Student: But, that doesn't prove which one it would be.
Teacher: Well, listen if you took copper sulfate, copper oxide, and copper chloride and burned them all. And you get green, green, and green then it would indicate that this must be due to the copper.

Teacher Guides Thinking of Student Without an Answer

(1) Student reads question: Can pure substance such as
elements be distinguished by their
properties? Explain.
Student: I don't have it.
Teacher: What properties can be used? Think of the
properties that are available. (Teacher
holds up a piece of steel tubing). What is
this made of?
Student: Steel.
Teacher: What is this made of? (holds up a wooden
block)
Student: Wood.
Teacher: How can you tell?
Student: Looks.
Teacher: What looks different about it?
Student: Color.
Teacher: What else?
Student: Texture.
.....These are all properties, also color of flame
when it burns is a property.

Teacher Uses A Practical Application To Assist Understanding

(1) ....Do any of you cook over gas stoves? When you
spill milk on the gas flame you get an orange flame.
Give me a reason why?
Student: The elements burn off milk to give off flame
colors.
Teacher: Look at your list to see which element is
being burned to give the yellow flame, or
orange flame?
Student: Calcium.
Teacher: Calcium, is there calcium in milk?
Student: Yes!.....
Teacher: Give me a practical use, an everyday use, of
identifying elements by means of the flame
tests.
Student: If traces of a substance are found on the
hands or finger prints of a criminal, need to
identify the substance.

APPENDIX P

SUMMARY OF SLIC CHECKLIST OBSERVATIONS

TABLE 33

SLIC CHECKLIST OBSERVATION

GRADE 7 CLASS

Interaction Cagetory	Number of Times Interaction Observed Investigation 1			Investiagation 2			Investiagation 3		
	K	J	O	K	J	O	K	J	O
(1) Shows									
(2) Manipulating Apparatus	10	8		18	9	5	18	18	12
(3) Transmits Information		2				1	1		2
(4) Asks Questions		1		1	1		2	1	4
(5) Listens		1		1	1		2	1	3
(6) Observes Passively	1	1			3	7		2	2
(7) Reads Lesson									
(8) Writes Notes		2					16	16	4
(9) Gets Supplies		2		1	2	2	3	6	8
(10) Non-Lesson Related Behavior	2	1		1	3	2	9	8	17
Total Number of Interactions	13	18		22	19	17	51	52	52

Note. K = Karl's interactions
J = Jacob's interactions
O = Olaf's interactions
(Olaf came into study at investigation 2, original student dropped out)

TABLE 34

SLIC CHECKLIST OBSERVATION

GRADE 8 CLASS

Interaction Cagetory	Number of Times Interaction Observed					
	Investigation 1			Investigation 2		
	M	A	I	M	A	I
(1) Shows						
(2) Manipulating Apparatus	15	17	21	15	13	13
(3) Transmits Information	1	1	2	1	3	1
(4) Asks Questions		1	3		1	3
(5) Listens	2	2	4	1	1	1
(6) Observes Passively	1	4	5		1	1
(7) Reads Lesson	4	5	5			
(8) Writes Notes	6	13	19	8	4	8
(9) Gets Supplies	1	4	6	2	3	5
(10) Non-Lesson Related Behavior	1	8	2	1	3	2
Total Number of Interactions	31	55	67	28	29	34

Note. M = Marie's interactions
A = Alfred's interactions
I = Irene's interactions

TABLE 35

SLIC CHECKLIST OBSERVATION

GRADE 9 CLASS

Interaction Cagetory	Number* of Times Interaction Oberserved								
	Investigation 1			Investigation 2			Investigation 3		
	N	R	E	N	R	E	N	R	E
(1) Shows									
(2) Manipulating Apparatus	13	5	1	19	25	2	30	53	22
(3) Transmits Information	5	1		5	2	2	5	4	1
(4) Asks Questions	4	1	1	1	3		9	9	1
(5) Listens	3	1		2	2	6	6	7	8
(6) Observes Passively		8	8			15	6	8	29
(7) Reads Lesson	3	4	4	4	2	7			
(8) Writes Notes	6	7	6	2	3	6	3	6	6
(9) Gets Supplies			3	4	6		2	14	14
(10) Non-Lesson Related Behavior	1	3	7	9	7	9	14	13	24
Total Number of Interactions	35	30	30	46	50	47	75	114	105

Note. N = Nicolas's interactions
R = Rachel's interactions
E = Elaine's interactions

APPENDIX Q

PERMISSION LETTERS

PERMISSION FORM

Dear Parents or Guardians:

I am an Edmonton Public School Board science teacher who is currently at the University of Alberta working toward a doctoral degree in education. With my research study I will try to get a better understanding of laboratory work in science at the junior high school level.

For this study I wish to gather information in your school for a period of three weeks (within the months of April and early May). During this time I propose to do the following:

(a) observe and record what the teacher and students do during laboratory work.
(b) have casual conversations with some students during laboratory work.
(c) tape record interviews with randomly selected students and the teacher.
(d) tape record class discussions occurring before and after performing of the laboratory experiments.
(e) examine randomly selected students' notes and request permission to photocopy specific segments.
(f) request students within the class to complete an attitude questionnaire of laboratory activities.

Throughout the project, including the thesis, confidentiality and strict anonymity of the schools and participants (students and teachers) will be maintained. Student and teacher participation is voluntary. All tape recordings will be destroyed after analysis has been completed. Any information gathered will be used solely to complete the Ph. D. thesis, and perhaps thereafter be put in a paper for a professional publication.

I would appreciate the involvement of your son or daughter in this endeavor, and consequently I am requesting your permission. Please respond by checking one of the two statements on the form below and signing your name in the space provided. It would also be appreciated if your return this permission form to the school as soon as possible. If you have any questions about this do not hesitate to phone me at 432-5723.

I wish to thank-you for giving this matter your time and consideration.

Sincerely,

G.E. Jeske

- -

I give permission for my child's involvement in Mr. Jeske's project. ___________

I do not wish to have my child involved in Mr. Jeske's project. __________

Parent or Guardian Signature ____________________________

G.E. Jeske
4348 - 68 Street
Edmonton, Alberta
T6K 0T8
March 26, 1990

Deane Jensen
Curriculum: Courses of Study and Resources
Centre for Education
One Kingsway
Edmonton, Alberta T5H 4G9

Dear Mr. Jensen:

I am enrolled in the Department of Secondary Education at the University of Alberta as a doctoral student in science education. Presently, I am preparing my thesis which is a study of the use of science laboratory activities at the junior high school level.

In my thesis I would like to include examples of laboratory investigations which students were engaged in while data for the study was being collected. For purposes of microfilming, the National Library of Canada requires that when students are including in their thesis previously copyrighted materials, that letters of permission from the person/s or publishing company holding the copyright be included in the final copies of the thesis.

The investigations from C.R.I.B. for which I am requesting permission to have included in my thesis are:
Grade 7
(1) The parts of a green plant I, B1, 1.S.1
Grade 8
(1) The specific gravity of minerals III, A1, 1.S.6
(2) Research activity on mineral tests: III, A1, 1.S.9
Grade 9
(1) Problem: How may elements be distinguished by flame tests? V, A1, 1.S.2
(2) Problem: How may one distinguish between a mixture and a compound. V, A1, 1.S.3

Yours truly,

G.E. Jeske

G.E. Jeske
4348 - 68 Street
Edmonton, Alberta
T6K 0T8
March 16, 1990

Ginn and Company
3771 Victoria Park Avenue
Scarborough, Ontario M1W 2P9

Dear Madam or Sir:

I am enrolled in the Department of Secondary Education at the University of Alberta as a doctoral student in science education. Presently, I am preparing my thesis which is a study of the use of science laboratory activities at the junior high school level.

In my thesis I would like to include examples of laboratory investigations which students were engaged in while data for the study was being collected. For purposes of microfilming, the National Library of Canada requires that when students are including in their thesis previously copyrighted materials, that letters of permission from the person/s or publishing company holding the copyright be included in the final copies of the thesis.

The investigation from the textbook entitled Life Science: A Problem Solving Approach, Carter et al, Ginn (1977) for which I am requesting permission to have included in my thesis are:
(1) Problem 14-1, What is one kind of food produced by green plants? (P. 261-262)
(2) Problem 14-2, When do plant leaves contain starch? (P. 264-266).

Yours truly,

G.E. Jeske